J. A. BOWNOCKER, State Geologist

GEOLOGICAL SURVEY OF OHIO

Volume XI.

Comprising Bulletins 12, 13, 14 and 15 of the Fourth Series

COLUMBUS,
1913

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To Governor James M. Cox:

DEAR SIR: I transmit herewith Volume XI of the Geological Survey of Ohio, consisting of Bulletins 12, 13, 14 and 15 of the Fourth Series.

These bulletins have already been distributed, and are assembled in this form as provided by statute. By action of the last session of the General Assembly the publication of the bulletins in this form has been discontinued, and therefore this will close the series of volumes.

Respectfully submitted,

J. A. BOWNOCKER, *State Geologist.*

COLUMBUS, OHIO, May 15, 1913.

THE SURVEY IN ITS RELATIONS TO THE PUBLIC.

The usefulness of the Survey is not limited to the preparation of formal reports on important topics. There is a constant and insistent desire on the part of the people to use it as a technical bureau for free advice in all matters affecting the geology or mineral industries of the State. A very considerable correspondence comes in, increasing rather than decreasing in amount, and asking specific and particular questions on points in local geology.

The volume of this correspondence has made it necessary to adopt a uniform method of dealing with these requests. Not all of them can be granted, but some can and should be answered. There is a certain element of justice in the people demanding such information, from the fact that the geological reports issued in former years were not so distributed as to make them accessible to the average man or community today. The cases commonly covered by correspondence may be classified as follows:

1st. Requests for information covered by previous publications.—This is furnished where the time required for copying the answer is not too large. Where the portion desired cannot be copied, the enquirer is told in what volume and page it occurs and advised how to proceed to get access to a copy of the report.

2nd. Requests for identification of minerals and fossils.—This is done, where possible. As a rule the minerals and fossils are simple and familiar forms, which can be answered at once. In occasional cases, a critical knowledge is required and time for investigation is necessary. Each assistant is expected to co-operate with the State Geologist in answering inquiries concerning his field.

3rd. Requests from private individuals for analysis of minerals and ores, and tests to establish their commercial value.—Such requests are frequent. They cannot be granted, however, except in rare instances. Such work should be sent to a commercial chemical laboratory. The position has been taken that the Geological Survey is in no sense a chemical laboratory and testing station to which the people may turn for free analytical work. Whatever work of this sort is done, is done on the initiative of the Survey and not at the solicitation of an interested party.

The greatest misapprehension in the public mind regarding the Survey is on this point. Requests for State aid in determining the value of private mineral resources, ranging from an assay worth a dollar up to drilling a test well costing several thousand dollars, represent extreme cases. At present there is no warrant for the Survey making private tests, even where the applicant is entirely willing to pay for the service. In many cases individuals would prefer the re-

port of a State chemist or State geologist to that of any private expert, at equal cost, because of the prestige which such a report would carry. But it is a matter of doubt whether it will ever be the function of the Survey to enter into commercial work of this character; it certainly will not be unless explicit legal provisions for it are made.

4th. Requests from a number of persons representing a diversity of interests, who jointly ask the Survey to examine into and publicly report upon some matter of local public concern.—Such cases are not common. It is not always easy to determine whether such propositions are really actuated by public interest or not. Each case must be judged on its merits. The Survey will often be prevented from taking up such investigations by the lack of available funds, while otherwise the work would be attempted.

The reputed discovery of gold is one of the most prolific sources of such calls for State examination. It usually seems wise and proper to spend a small sum in preventing an unfounded rumor from gaining acceptance in the public mind, before it leads to large losses and unnecessary excitement. The duty of dispelling illusions of this sort cannot be considered an agreeable part of the work of the Survey, but it is nevertheless of very direct benefit to the people of the State.

GEOLOGICAL SURVEY OF OHIO

Volume XI

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FOURTH SERIES, BULLETIN 12

THE BREMEN OIL FIELD

By J. A. BOWNOCKER

OCTOBER, 1910

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CHAPTER I.

THE BREMEN OIL FIELD.

The discovery of the Bremen oil field is a result of the close association of oil and gas. As is well known, every oil well is to a greater or less extent a gas well, and large gas fields are seldom remote from oil. Gas was discovered in the Clinton at Lancaster February 1, 1887, and at Newark in May of the same year.[1] In the spring of 1888 the fuel was found at Thurston. These discoveries, while not large, were at widely separated localities and insured extensive drilling. The result was the discovery and development of one of the finest gas fields ever known.

Oil, however, is usually more profitable than gas, and almost from the time of the discovery of the latter in the Clinton the search for oil has gone on. For years the result was discouraging, but the driller for oil is as persevering as the miner who seeks the precious metals. The first pool of commercial proportions secured in the Clinton formation was in Jackson Township along the northern border of Vinton County. In August, 1899, a well was completed, which, while not large, was profitable, and of course other holes were started at once, the result being the location and development of a small pool of oil. The second discovery of the fuel in a commercial way was in the southeastern corner of Knox County in August, 1904. In December of the following year a paying well was completed near Butler in the southeastern part of Richland County, and started flowing at an estimated rate of 200 barrels the first day. The oil was "water white," and the field is one of the most remarkable yet found in Ohio, though it was not a large producer.

In the early spring of 1907 a well was completed on the Weingartner farm between Pleasantville and Rushville in Fairfield County, and began flowing oil at approximately 75 barrels per day. In July of the same year a well was completed on land of Frank Kittle in the adjacent township of Brush Creek and proved to be a success. These two wells mark the opening of the Bremen field and the real beginning of the Clinton as a source of oil.

Location.—At present it includes parts of Rush Creek and Richland Townships of Fairfield County; Jackson, Reading and Pike Townships, and to a smaller extent several others of Perry County. As the map shows, it is not one large field, but rather a number of small more or less disconnected areas. Thus we have the Pleasantville, Rushville, Bremen, Junction City and Straitsville pools. Whether or not further drilling will unite these is an open question. At present the indications

[1]Orton, Edward. *Geol. Surv. of Ohio*, Vol. VI, pp. 370-372; also Bownocker, J. A., Bull. I, Fourth Ser., pp. 102, 106, 107.

are that the field is somewhat spotted, but that the Bremen and Junction City pools, at least, will unite, forming a continuous area from Bremen to New Lexington.

Early Drilling.—The discovery of this pool is due in no small measure to the confidence and perseverance of one man, Mr. J. E. Purvis. Its subsequent development is likewise due quite largely to the same individual. Nearly twenty years ago he secured options on about 5,000 acres of land around Bremen and attempted to organize a company to drill for oil. He believed that fuel was present because of the great reservoirs of natural gas a few miles to the west. Failing to enlist the necessary capital, the options were lost, and two more attempts had to be made before drilling began. About 1895 the Rush Creek Oil & Gas Company was organized, the capital stock at first being $10,000, but was increased later to $50,000. Stock to the value of $18,000 was sold.

The first well was drilled early in 1896 on the Stewart farm a short distance north of Bremen. When a depth of 1,790 feet had been reached, a heavy flow of gas, estimated at 5,000,000 cubic feet per day, was encountered, and drilling ceased. Lines were laid to Bremen, Rushville and West Rushville, giving those villages their first supply of natural gas, but about eighteen months later a flood of salt water ruined the well. So favorable an impression did this well make on capitalists that $100,000 was offered for the leases held by the company, which would have left $82,000 to be distributed among stockholders, but the offer was rejected.

The next venture was on the Steamen farm, a mile and a quarter southeast of Bremen. The Clinton sand was found in 1896, at a depth of about 2,510 feet, and contained some oil, but the shales above the sand caved badly, and in about six months the well was abandoned without having shown what it was worth. Mr. Purvis thinks it would have produced 15 barrels per day.

The third effort of the company was on the Rowles farm, about the same distance southwest of Bremen. Fourteen months were consumed in drilling this well, which was less encouraging than either of the preceding ones. At about this stage the company went into a receiver's hands, and the double liability law was enforced that debts might be paid. In this way the Rush Creek Oil & Gas Co. went out of existence.

Late in 1896, Purvis, with two practical oil men, formed a partnership and drilled a well a mile and a quarter northeast of Bremen on the Nixon farm. The Clinton sand showed oil, but not enough, it was thought, to warrant shooting, so the well was abandoned and the partnership terminated.

Within the next ten years Purvis took up leases two or three times, but could not raise the money necessary for drilling. In the spring of 1907 oil was gotten in a well drilled for gas about seven miles northwest of Bremen. The coveted fuel had now been disclosed on three sides of

the village, and naturally this strengthened the conviction of Purvis that oil in commercial quantities existed in the vicinity of Bremen and made possible the organization of the Bremen Gas & Oil Co. in 1907.

DISCOVERY AND DEVELOPMENT.

Bremen Pool.—On May 17, 1907, the company just named, and which was to play so important a part, was organized. The capital stock was fixed at $50,000, in shares of $25.00; about four hundred and twenty-eight shares were sold and eighty additional ones were given in exchange for about 10,000 acres of land that had been leased by Purvis & Ruff, in Rush Creek Township, Fairfield County, and Jackson Township, Perry County, The board of directors chosen consisted of J. E. Purvis, A. F. Turner, L. Olive, L. H. Kennedy, Lewis E. Ruff, Charles Bloom and W. S. Turner, all of Bremen, Ohio. The board organized by electing A. F. Turner, President, and L. E. Huddle, Secretary.

The first place selected for testing was the farm of F. M. Kittle, on the northeast quarter of Section 11 of Rush Creek Township. No special reason existed for this location; it was simply one of the leases held by the company and was neither more nor less promising than other tracts. Drilling began June 12, 1907, and the tools penetrated the Clinton sand late in July. Some oil was found and the sand was shot with 60 quarts of nitroglycerine that was hauled in a wagon from near Marietta. In drilling, the casing extended simply to the base of the Berea, but when oil was found a string of 2,574 feet was set on the top of the Clinton, thus insuring a dry hole so far as water was concerned. After shooting, the well flowed several times, but the water proved too strong. When the casing had been inserted and the well cleaned, a pump was attached and the production started at 10 barrels per day. It is now (June, 1910), pumping about half that quantity. While this well was not much of a success it was encouraging, and in August a second one was begun. Stockholders urged that leases nearer Bremen be tested, and to satisfy them a location was made on the farm of G. W. Baldwin, just north of the village. The Clinton sand was found, but it was hard and without oil or gas. A shot of 80 quarts of nitroglycerine did not improve matters.

These two wells, one a complete failure and the other a small producer, emptied the treasury of the company, but the stockholders with few exceptions doubled their shares and the drill was started again. The location was near their first well and on the farm of J. W. Huston, southeast quarter of Section 2. The Clinton sand was penetrated about October 1, 1907, and began flowing oil at the approximate rate of 140 barrels per day. Thus after nearly twenty years of effort Purvis began reaping his reward. The well was very profitable and in July, 1910, was pumping about 20 barrels each day. Naturally the company did

not go far for its next location which was on the Householder farm, adjoining the Huston on the east. The Clinton sand was reached in February, 1908, and the well began flowing at the rate of 250 barrels per day; in July following, it was producing at the rate of 100 barrels, and two years later 10 barrels daily. Of course this well attracted wide attention and the rush to the new field began. Leases were sought after far and near, and rentals as high as $12.50 an acre per year were paid. The Purvis farm joins the Householder on the east and a well completed on it July 10, 1908, began producing 300 barrels per day; by September 1, 1910, this rate had decreased to 8 barrels.

Other wells were sunk by this company as fast as the drill could be forced down and with marked success, obtaining a daily production of 1,000 barrels in 1909 and maintaining this for the following 12 months or thereabouts. Stock rose rapidly in value and in May, 1909, sold as high as $625 a share. By January 1, 1910, twelve 50 per cent. dividends had been paid. The oil commands the Pennsylvania price and sold for $1.78 per barrel during approximately the first two years of the company's history. It then began dropping and reached $1.30, at which it is now selling. By the close of 1909 the company had drilled 90 wells and 70 of these were producers. The decline in the price of oil naturally interfered with dividends, and by July 1, 1910, the stock had dropped to about $300 a share. By January 1, 1910, the Carter Oil Company had secured a controlling interest in the company, and its future is in the hands of that great corporation. Among its first acts was the sale at par and pro rata among the stockholders of the balance of the $50,000 treasury stock of the Bremen Gas and Oil Company. It holds leases of about 8,000 acres in the Bremen field, and will doubtless develop that as rapidly as the condition of the market warrants. No dividends have been paid since January 1, 1910, and none were expected in the near future (July, 1910).

Thus far, our review has been limited to the fortunes of the Bremen Company. Attention will next be given briefly to a few of the scores of organizations that were formed early in the history of the development. The Avelon Oil & Gas Company was formed in January, 1908, by J. E. Purvis. The capital stock was $75,000, of which $41,000 was sold at $25 a share. Purvis turned over to the company leases on about 2,500 acres, receiving as compensation $2,500 in cash, $10,000 in stock and a promise of one-sixteenth of whatever oil might be secured. Drilling began in the early spring of 1908, on the Elder farm, about a quarter of a mile northeast of the Householder, which proved so great a source of wealth to the Bremen Company. Only a show of oil was secured; the well was shot and then abandoned. The second attempt was on the Holliday farm, about three miles northeast of Bremen, and a 20-barrel producer secured. The third well was located about 200 feet to the west and proved a bonanza. Purvis states that it started at approximately 300 barrels

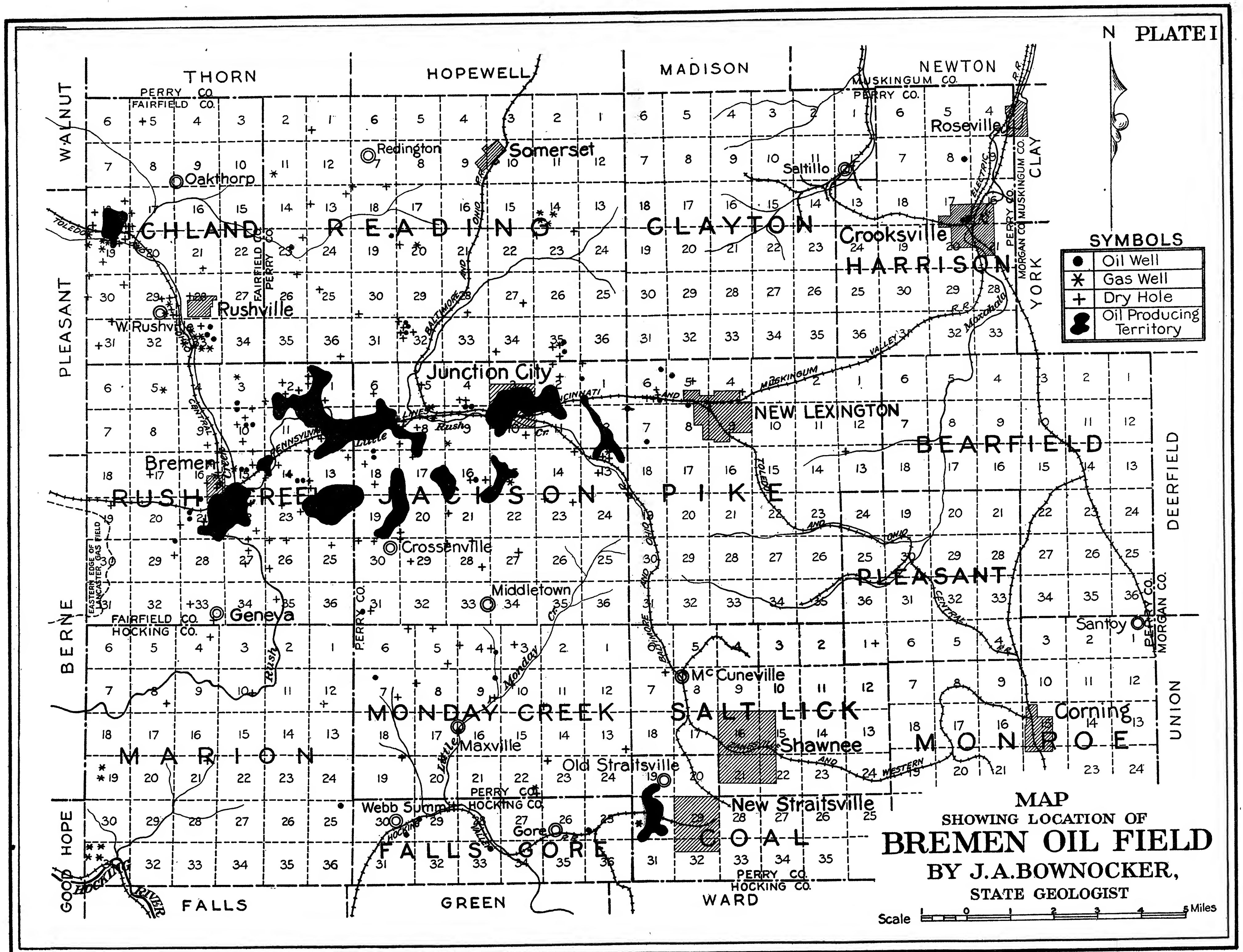


PLATE I
N
SYMBOLS
Oil Well
Gas Well
Dry Hole
Oil Producing Territory
MAP
SHOWING LOCATION OF
BREMEN OIL FIELD
BY J.A.BOWNOCKER,
STATE GEOLOGIST
Scale
5 Miles
THORN
HOPEWELL
MADISON
NEWTON
WALNUT
PLEASANT
BERNE
GOOD HOPE
FALLS
GREEN
WARD
CLAY
YORK
DEERFIELD
UNION
HIGHLAND
READING
CLAYTON
HARRISON
RUSH CREEK
JACKSON
PIKE
BEARFIELD
PLEASANT
MARION
MONDAY CREEK
SALT LICK
MONROE
FALLS GORE
COAL
PERRY CO.
FAIRFIELD CO.
MUSKINGUM CO.
MORGAN CO.
HOCKING CO.
Somerset
Redington
Oakthorp
Rushville
W. Rushville
Bremen
Junction City
New Lexington
Crooksville
Roseville
Saltillo
Crossenville
Middletown
Geneva
Santoy
Corning
McCuneville
Shawnee
Maxville
Old Straitsville
New Straitsville
Webb Summit
Gore
EASTERN EDGE OF LANCASTER GAS FIELD
HOCKING RIVER

a day, and averaged 200 barrels for 90 days. September 1, 1910, its production was 20 barrels. The company drilled in all about 15 wells, 11 of which were producers. Two dividends, each of 25 per cent., have been paid, and the stock has sold as high as $300 a share; July 1, 1910, the price was $25.

The Planet Oil & Gas Company was organized late in 1907. It secured two leases about three miles east of Bremen, and drilled sixteen wells, all of which produced. The wells varied in output from 5 to 300 barrels per day, and the profits were large, though the actual figures are not in possession of the Survey.

The David Rodafer Oil & Gas Company, organized April 1, 1909, has been very successful. Its capital stock was $50,000, in shares of $25. The company secured control of the old Rodafer farm of about 145 acres, giving the owners $22,500 in stock for the lease. The land joins Bremen—in fact, part is within the village—and is situated largely in the valley of Rush Creek. Drilling began in June, 1909, and 17 wells, all producers, had been completed by July 1, 1910. In size these ranged from 5 to 375 barrels per day. The maximum production of the lease was 1,100 barrels a day, and on the date just mentioned was 800 barrels. The company has room for six or eight more wells, but reported that these would not be drilled at once. No dividends had been paid, the income having been used for development, but with the cessation of drilling, handsome returns should be received by the stockholders.

The Great Expectation Oil & Gas Company was organized in the autumn of 1909. At first it had only one acre of ground optioned, and this was located about a half mile south of Bremen. A well drilled on this the same season began producing about 30 barrels of oil per day. The company then secured a half-acre lot in the village of Bremen, but outside of the corporation line, and on this a well was drilled. The initial production, according to Purvis, was at a rate of 500 barrels per day, making it the largest producer from the Clinton sand yet secured. Strange to state, the company has not secured additional leases or drilled more wells, but is content with the results secured. By July 1, 1910, it had paid dividends of 650 per cent.

From the first producing territory, about three miles northeast of Bremen, the drill moved in all directions, but with little success to the north and west. Southward the results were more favorable, and by 1908 wells were being secured in the valley of Rush Creek. In the spring of 1909 the drill was at work near Bremen, and late in the year on town lots. Much money has been wasted in this enterprise—not only have wells been drilled on adjacent lots, but in at least one case two have been put down on the same lot. Sometimes the derricks were so close together that there was scarcely room for the tools. Such crowding is a shameful waste of time and money, for what would be profitable with the usual spacing of wells must be unprofitable when a half dozen are drilled where one should be. By July 1, 1910, thirty wells, six of which

were failures, had been drilled in Bremen, and three strings of tools were at work. The productive territory appears to lie in the main along the eastern side of the town, but further drilling may extend it westward.

During the first year the oil was pumped into tanks along the railroad, and then run by gravity into tank cars. In 1908 the Buckeye Pipe Line Company erected a pumping station in the valley at Bremen, and laid a three-inch line. A little later this was replaced with a four-inch line, and this in turn with a six-inch.

Having reviewed the history of the development around Bremen, attention will be given to other pools in the same part of the State.

Pleasantville Pool.—In March. 1907, a well was completed on the Weingartner farm, Section 18 of Richland Township, Fairfield County, about midway between the villages Pleasantville and West Rushville. It will be noted that this was prior to the first well in the Bremen field proper, which dates from July following. The well began flowing at the rate of about 75 barrels per day. Other wells were drilled as fast as the tools could be forced down, but by the close of 1908 the limits of the field had been determined, and little drilling has been done since that time. The best well reported is on the Stevenson farm, and started flowing at about 200 barrels per day.[1] The producing territory includes parts of Sections 18 and 19, on which about a score of oil wells has been obtained. To the south a few gas wells have been secured, and immediately to the west lies an arm of the great Central Ohio gas field. Eastward from the oil wells seven dry holes have been sunk, and no direct extension in that direction needs be expected.

Rushville Pool.—The Rushville Oil & Gas Company drilled a well on the Wikoff farm, on the southeast quarter of Section 33, about one mile south of the village, in the summer of 1909, and secured a gas well that started producing 1,887,000 cubic feet per day. Two further attempts on the same farm brought similar results. The gas is disposed of to the Logan Gas & Fuel Company at five cents per thousand cubic feet. The next effort was on the Morehead farm, which joins the Wikoff on the north, the result being an oil well which started flowing at the rate of about 75 barrels the first day. Another test on this farm showed oil, but before the well had been cleaned and put to pumping the company sold its holdings. The production is reported to have started at 30 barrels a day. A third well was completed on the same farm in the summer of 1910 with favorable results, and two sets of tools were busy in the field. No dry holes were reported to the east, and an important extension may be made in that direction. Several gas wells are found farther west, though the production from these is not large, and two additional ones were secured near West Rushville, one in the valley near the T. & O. C. R. R. station and the other near the southeastern edge of the village. Four dry holes near these two wells dampen the enthusiasm of the prospector.

[1]An analysis of the oil from this field may be found on page 17.

PLATE II.

Partial View of the Bremen Pool, with the Village in the Background.

Junction City Pool.—Naturally the success achieved by drilling a few miles to the west aroused the enterprising citizens of Junction City, and on March 14, 1909, the Alberta Oil & Gas Company began drilling within the corporation. The Clinton sand was found at a depth of 2,854 feet, and after shooting with 40 quarts it began flowing oil at the approximate rate of 150 barrels a day. By the middle of July, 1910, it still flowed occasionally, but the production had dropped to 15 barrels per day. The well was sufficient to start the boom, and others were sunk as rapidly as possible. By the date just given, 65 wells, only one of which was dry, had been completed within the corporation of 640 acres, and three strings of tools were at work. Since March, 1910, work has been quieter and the excitement has subsided. Probably the decrease in the price of oil and the fear of further reductions have been the most potent agency in checking the drill. Wells have varied greatly in size, from those scarcely large enough to warrant tubing to Crown No. 2, which was shot about December 1, 1909, and started flowing at the rate of 300 barrels a day. By the middle of the following July its daily output had dropped to 30 barrels. The Perry-Noble No. 3 was another large producer. It was shot April 16, 1910, and started flowing at the rate of 225 barrels a day. Three months later this had dropped to 45 barrels. Of the 65 wells in the corporation, not more than a half-dozen started at 10 barrels or less. Wells of this size are pumped from the start; others flow at first.

Of the many companies formed in the Junction City field only five have paid dividends to date (July 15, 1910). These are as follows: The Holiday Oil & Gas Company, 20 per cent.; The Electric Oil & Gas Company, 10 per cent.; The Alberta Oil & Gas Company, 10 per cent.; The Capitol Oil & Gas Company, 10 per cent.; and The Shamrock Oil & Gas Company, 10 per cent. The receipts, in large part, have generally been used for further drilling; otherwise dividends would have been larger. Much drilling has been done and is still in progress south and west of Junction City, the results being similar to those given for other parts of the Bremen field. The limits of the territory have not been determined.

Some farms in the vicinity of Junction City have been leased since the drilling of the Kochensparger well in 1902. The price has varied from 50 cents to $3.00 per acre, the common figure being $1.00.

New Straitsville Pool.—This lies in Sections 19 and 30 in the extreme northwestern corner of Coal Township. The first test of the Clinton sand was made on the Jones farm, southeast quarter of Section 19. The well was drilled by the Purvis-Martin Oil & Gas Company and was completed July 4, 1909, the Clinton sand being struck at 3,202 and found 25 feet thick. For ten months the well averaged 22½ barrels of oil per day. It was then cleaned and shot for the second time and continued producing at the rate just mentioned. In August, 1909, the company began its second well, located on the Martin land due south of the center of Section 30. The "Big lime" was reached at 2,115 feet; at 2,725

it yielded a heavy flow of brine and at one time the well contained more than 3,000 feet. The top of the Clinton sand was reached at 3,140 feet and the bottom at 3,168. It was shot with 60 quarts of nitroglycerine, but the only reward was a small flow of gas estimated at 250,000 cubic feet per day, and 2½ barrels of oil. The gas was used for additional drilling, and the well is now pumped for oil.

Well No. 2 on the Jones farm was located about 700 feet south of No. 1, and was completed in November, 1909. The Clinton sand was found at a depth of 3,236 feet and the bottom at 3,261 giving it a thickness of 25 feet. The top 4 feet of the sand were very soft and gave a heavy flow of gas, estimated at 2,000,000 cubic feet per day, but the closed or rock pressure was only 460 pounds. After a short time 1,200 feet of salt water appeared in the well and it was ruined. The source of this heavy flow of brine appears to be a mystery to the company, but it doubtless had its origin in the "Big lime." The well was shot, but made no oil at all, and was abandoned.

The fourth well of the company was Martin No. 2 and was located about 50 feet south of the center of Section 30. The desired sand was reached at 3,104 feet and measured 38 feet in thickness. The sand was not uniform; at the top it was quite soft while below a couple of small breaks seemed to be present. The sand was shot with a heavy charge—about 100 quarts—and a 5-barrel well secured. The company next drilled Martin No. 3, about 1,400 feet due west of No. 2 and on the same farm. It was completed early in July, 1910, and was shot with 60 quarts, but the only reward was a showing of oil and some gas, and it will, in all probability, be abandoned. A location has been made north of the oil well on the Jones farm, but the result cannot be forcasted.

The Columbus Hocking Coal & Iron Company has made two tests to the Clinton on its property in this township. The first was on the northeast quarter of Section 30 and was completed late in 1909. After having been shot with 60 quarts the well began producing at the rate of 35 barrels a day, and this was maintained until the middle of the following May when an accident occurred stopping the well. The second test of this company was located 1,700 feet southeast of the first one. It was completed in December, 1909, and after having been shot with 60 quarts of nitroglycerine began flowing about 75 barrels of oil a day. By July 20 of the ensuing year it was producing 50 barrels, thus demonstrating excellent staying qualities. The well has never been pumped, but flows quite regularly at intervals of four hours.

One additional well remains to be mentioned. This is on the farm of the Clancey heirs near the western edge of New Straitsville. It was drilled by the Ebenezer Oil & Gas Company and the Clinton sand was penetrated June 25, 1910. When visited the well had not been cleaned and connected with the tank, so its capacity was not determined. The density of the oil was 46° B. and the temperature 78° F.[1] The well head is 760 feet above sea level, and the Clinton sand, which was reached at a

[1]For analysis of this oil see p. 17.

PLATE III.

The Crowding of Derricks Along the Southern Edge of Bremen.

depth of 3,106 feet, lies 2,346 below. Since this field was visited a well has been completed near the corporation line, the sand, about 25 feet thick, having been struck at a depth of 3,129 feet. It began producing oil at from 30 to 40 barrels a day.

The Clinton sand in this pool is persistent and quite thick. Its color is usually gray and its texture varies from well to well. Little or no water occurs in the sand, but it is abundant in the "Big lime."

Acknowledgment is made to Hon. E. S. Martin, of New Straitsville, for the facts pertaining to this pool.

Production of the Field.—This is shown by the following which has been provided by the Buckeye Pipe Line Co., Macksburg Division. As will be seen the production has risen irregularly to May, 1910, when the maximum was reached. Less drilling and hence fewer new wells since that time are responsible for the decrease. The indications are that the output will continue to shrink for months hence, and it may be that the productionof May last will not again be equaled.

PRODUCTION BY MONTHS.

August	1907	1,245.08	
September	1907	1,186.98	
October	1907	1,515.48	
November	1907	4,810.72	
December	1907	7,940.13	
			16,698.39 Barrels.
January	1908	14,263.35	
February	1908	14,292.30	
March	1908	18,082.39	
April	1908	18,377.23	
May	1908	24,002.01	
June	1908	29,542.68	
July	1908	33,749.72	
August	1908	38,849.75	
September	1908	33,815.16	
October	1908	31,335.44	
November	1908	29,561.17	
December	1908	36,280.90	
			322,152.10 Barrels.
January	1909	33,086.44	
February	1909	30,970.54	
March	1909	38,420.87	
April	1909	39,324.70	
May	1909	42,163.97	
June	1909	58,182.32	
July	1909	65,289.10	
August	1909	77,892.90	
September	1909	96,287.54	
October	1909	109,473.33	
November	1909	104,583.97	
December	1909	103,608.09	
			799,283.77 Barrels.

January	1910	120,524.22
February	1910	119,172.23
March	1910	152,223.95
April	1910	171,413.42
May	1910	184,544.11
June	1910	164,814.51
July	1910	147,473.80
August	1910	148,822.76
September	1910	134,172.88
		1,343,161.88 Barrels.

Grand total.. ....2,481,296.14 Barrels.

Composition of Oil.—This has been determined by the United States Geological Survey, in co-operation with the Geological Survey of Ohio. A representative of the latter organization collected the samples and had them delivered at Washington, where the analytical work was done. All samples were taken directly from the well and then soldered. The results may be found on page 17.

Commenting on these analyses, Dr. David T. Day, of the United States Geological Survey, says: "The analyses of the Clinton oils submitted herewith show them to differ in no respect from the characteristic southwestern Pennsylvania oils and the light oils of West Virginia. They are characteristic Appalachian oils, yielding, as usual, considerable amounts of gasoline and a large percentage of illuminating oil. It is a curious circumstance that the dark green oil No. 3 should yield more gasoline than the light amber oil, which has evidently been filtered more thoroughly through dry shales. The great similarity between these oils and those of Pennsylvania and West Virginia is shown by the considerable proportion of paraffin wax and the low percentage of unsaturated hydrocarbons in the crude oil and in the burning distillate. It is hoped that in a short time further distillation of these oils can be made, by which the quality of the individual hydrocarbons may be estimated."

The Engler method for the distillation of samples of petroleum consists of very definite conditions for a fractional distillation in which the size of the flask, the rate of distillation, and in general all the manipulation processes are very specifically described.

The fraction designated as "To 150° C." includes the benzine and gasoline fraction or crude naphtha of the trade.

The fraction "150°-300°" includes the burning oil distillate or kerosene.

The fraction "Residuum" includes heavy lubricating oils, paraffin oils, etc.

The columns headed "Unsaturated Hydrocarbons" represent the portion of the oil that is removed by treatment with sulphuric acid in the process of refining.

ANALYSES OF OILS FROM THE CLINTON SANDSTONE.

Collected by	Date of Collection.	Serial Number.	Location of Well.	Depth to Sand.	Physical Properties. Gravity. Specific.	Physical Properties. Gravity. Beaume.	Color.	Odor.	Distillation by Engler's Method. Begins to boil °C.	By Volume. To 150°C. C. C.	To 150°C. Sp.gr.	150–300°C. C. C.	150–300°C. Sp.gr.	Residuum. C. C.	Residuum. Sp.gr.	Total C. C.	Sulphur.	Paraffine.	Asphaltum.	Water.	Un-saturated Hydro-carbons. Crude.	Un-saturated Hydro-carbons. 150–300 °C.
																	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
J. A. Bownocker	6–30–10	1	Fairfield Co., Bremen Coal, L. Groves well, No. 1.....	2.462	.7848	48.4	Green	Usual odor of Pennsylvania oils.	68	15	.7036	40	.7698	42	.8557	97	Not determined. Not more than trace.	8.33	None.	None.	11.6	4
J. A. Bownocker	7– 6–10	2	Vinton Co., Jackson Township, Clinton well No. 1..	2.480	.7959	45.9	Light Green		102	4	.7140	51	.7673	43.6	.8600	98		5.62			5.6	4
J. A. Bownocker	7–12–10	3	Fairfield Co., Pleasantville Pool, Ruff well No. 2....	2.345	.8046	44.0	Dark Green		96	10	.7195	43	.7751	45.8	.8647	98.8		5.36			10.	4
J. A. Bownocker	7–16–10	4	Perry Co., Crooksville, Ohio, Fuel Co., well No. 1	3.407	.8014	44.7	Light Amber		98	7	.7215	45	.7736	45.6	.8663	97.6		6.63			10	4
J. A. Bownocker	7–20–10	5	Perry Co., New Straitsville Pool, Ciancey well No. 1	3.106	.7923	46.7	Amber		80	17.5	.7141	33	.7753	45.7	.8706	96.2		8.30			10.8	6
J. A. Bownocker	8– 3–10	6	Knox Co., Bladensburg Pool McKee well............	2.771	.8469	35.3	Dark		75	14.0	.7201	26	.7973	52.1	.9063	92.1		4.17		Much	19.6	7

GEOLOGY OF THE BREMEN FIELD.

The territory is drained by Rush Creek and its tributaries, chief of which is North Fork. The valleys attain a maximum width of nearly a mile, and are very flat and usually poorly drained. The uplands vary from gently rolling to hilly; the Pleasantville pool illustrates the former and all others, outside of the valleys, the latter. In the western part of the field the surface rocks belong to the Mississippian (Lower Carboniferous), while farther east they lie in the Pennsylvanian (Coal Measures). Everywhere they consist essentially of sandstones and shales.

The surface rocks in the western part of the field lie at about the stratigraphical horizon of the "Big Injun" series which is so important a source of oil in the extreme southeastern part of Ohio and in West Virginia, but is void of both oil and gas in the Bremen field. The Berea sandstone is everywhere found at its proper horizon and occasionally makes a show of oil or gas. At Goble's station, near Junction City, several wells in this formation supply fuel for a brick yard and at Corning the rock has yielded oil in a commercial way for nearly 20 years.[1]

Well Records.—The thickness of the Clinton sand, its dip and position with reference to overlying formations, and the varying thickness of the latter are shown by well records. Starting in the Pleasantville pool and running southeast to McCuneville, near Shawnee, a distance of seventeen miles, conditions were found as follows:

Pleasantville pool; Ruff well No. 2, southeast quarter of Section 18; well head 975 feet above sea level:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	175	175
Berea sand	25	610
Casing 6¼ inch., 610 feet.		
Bedford and Ohio shales	880	1,490
Big lime	710	2,200
Casing 5 $\frac{3}{16}$ inch., 2,211 feet.		
Clinton sand	41	2,364
Gas at 2,331 feet.		
Oil at 2,339 feet.		
Total depth		2,368

This well produces oil in paying quantity, but so little water that it is a question whether any exists in the sand.

Kennedy No. 1, in valley of Rush Creek, near the station Rushville, well head 860 feet above sea level. Authority, S. W. Friesner, West Rushville, Ohio:

[1] Bownocker, J. A. *Geol. Surv. of Ohio,* Fourth Ser., Bull. I, pp. 257-265.

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe, 8 inch	37	37
Berea sand	35	667
Casing 6⅝ inch, 667 feet.		
Bedford and Ohio shales	990	1,657
"Big lime"	750	2,407
Casing 5 $\frac{3}{16}$ inch., 2,229 feet.		
Clinton sand	32	2,483

This well, which is situated two and one-half miles nearly due southeast of the preceding one, shows a thickening of 110 feet in the shales lying between the Berea and "Big lime" and 40 feet in the "Big lime" itself. In the Ruff well the Clinton sand is 1,348 feet below sea level and in the Kennedy, 1,591, a drop of 243 feet, or 97 to the mile. This well produces gas.

The next well is Householder No. 1, on Section 2 in the Bremen pool; well head 835 feet above sea level. Authority, W. S. Turner, Bremen, Ohio.

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	49	49
Berea sand	....	710
Bedford and Ohio shales	975	1,685
"Big lime"	790	2,475
"Big water" at 2,185 feet.		
Clinton sand	34	2,619
Bottom of well	....	2,620

This well, which is 3⅔ miles southeast of the Kennedy, shows a decrease of 15 feet in the thickness of the Bedford and Berea shales and an increase of 40 feet in the "Big lime." The top of the Clinton sand lies 1,750 feet below sea level, a drop of 159 feet from the Rushville well, or more than 43 feet per mile. As stated elsewhere the Householder began flowing 250 barrels a day.

Continuing southeast the valley of Rush Creek is reached at Flagdale, where the following record was secured from well No. 8, T. L. Griggs farm; elevation of well head 805 feet. Authority, Schrier and Kerr:

	Thickness. Feet.	To bottom of formation. Feet.
Mantle rock	55	55
Drive pipe 10 inch, 56 feet.		
Big Injun sand	100	235
Berea sand	33	718
Casing 8 inch, 720 feet.		
Bedford and Ohio shales	1,032	1,750
"Big lime"	798	2,548
Casing 6½ inch, 2,425 feet.		
Clinton sand	33	2,708
Total depth	....	2,717

This well is about 2½ miles southeast of the Householder and shows an increase in thickness of the "Big lime" of 8 feet; in the Bedford and Ohio shales of 57 feet, and a drop in the position of the Clinton sand of 120 or 48 feet to the mile. It produces oil in commercial quantities.

One more record is needed to complete this section within the limits assigned, and that is at McCuneville. The well head is 797 feet above ocean level, and the record provided by L. C. Laube follows:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe 17 inches	17	17
Through salt sand at 370 feet	....	......
Casing 10 inch, 370 feet.		
Berea sand	15	850
Bedford and Ohio shales	1,245	2,095
"Big lime"	870	2,965
"Big water" at 2,755 feet.		
Lime and shells at 3,094 feet.		
Clinton sand	32	3,148
Bottom of well, 3,165 feet.		

In comparison with the well at Flagdale this shows a thickening in the Bedford and Ohio shales of 213 feet; the "Big lime" of 72 feet, and a drop in the place of the Clinton sand of 449 feet or 52 feet to the mile.

For the sake of ready reference the dips of the sand are grouped together:

Pleasantville Pool to West Rushville	97	feet per mile
West Rushville to Householder well	43	" " "
Bremen Pool to Flagdale	48	" " "
Flagdale to McCuneville	52	" " "
Average dip	57	" " "

These figures show a varying dip, the greatest to the northwest and the least near the middle. It will be noted that they do not indicate an anticline—a structure that many geologists and prospectors regard as essential to oil or gas in marketable quantities. Plate IV shows diagrammatically these features and others of interest.

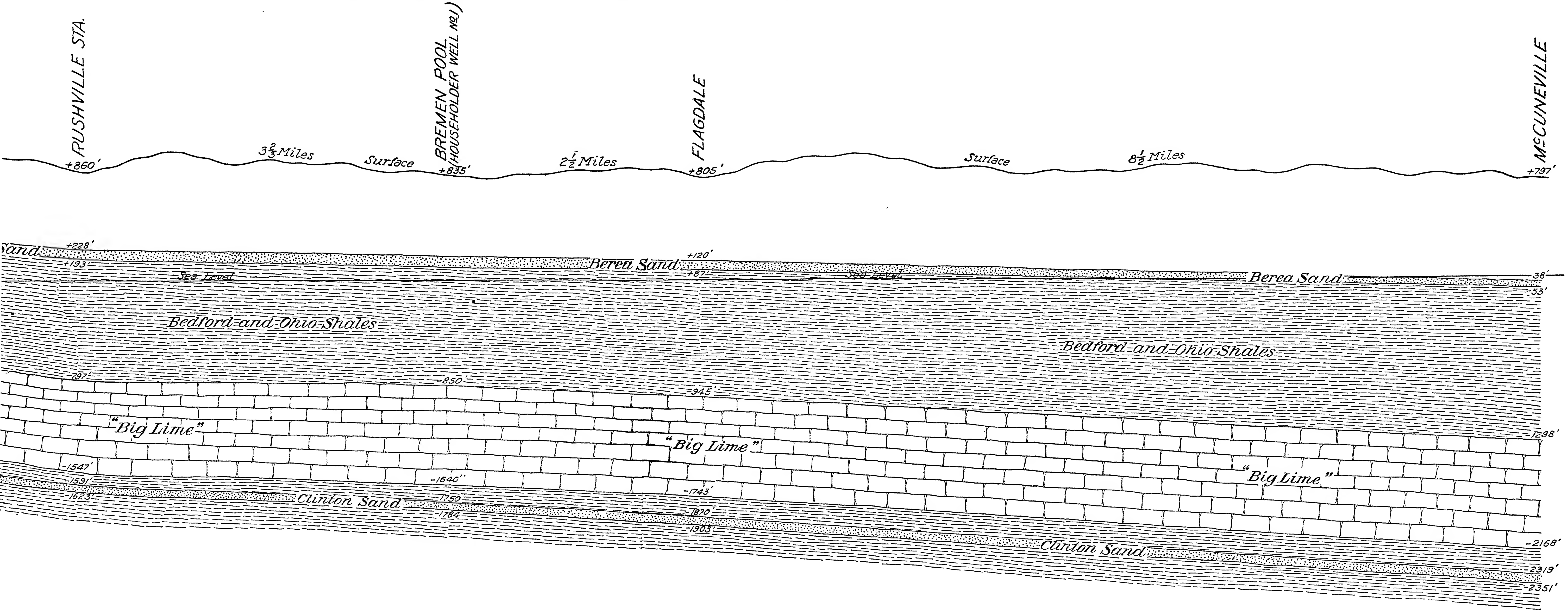
To show the changes in the formations along an east-west line a number of records from Lancaster to the vicinity of New Lexington will next be given.

Well drilled in 1886 in valley of Hocking River at Lancaster; elevation 812 feet. Authority, Edward Orton:

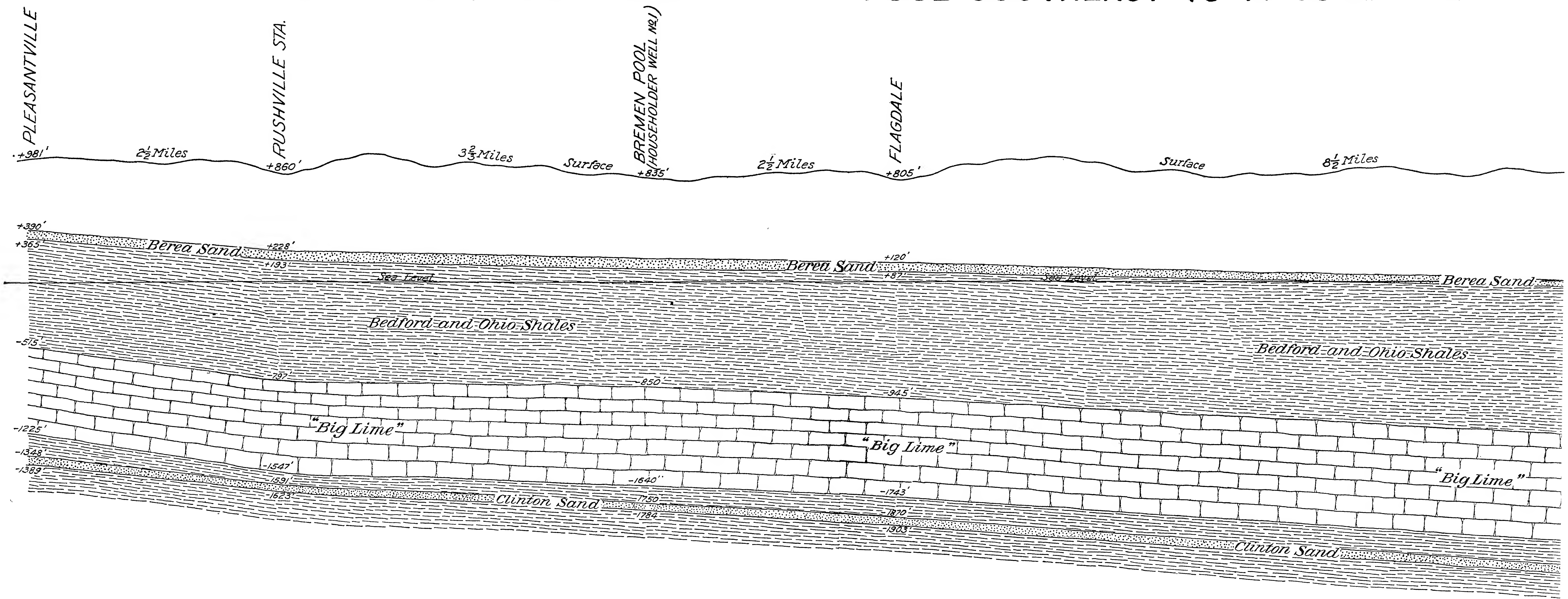
	Thickness. Feet.	To bottom of formation. Feet.
Drift	132	132
Cuyahoga and Sunbury shales	268	400
Berea sand	20	420
Bedford and Ohio shales	630	1,050
"Big lime"	700	1,750
Clinton sand at about 1,955 feet.		

PLATE IV

SECTION FROM PLEASANTVILLE POOL SOUTHEAST TO McCUNEVILLE



SECTION FROM PLEASANTVILLE POOL SOUTHEAST TO McCUNEVILLE



The next record is that of Morrow No. 1 at Berne, 5½ miles east of Lancaster; elevation of well head 815 feet. Authority, The Logan Gas & Fuel Company.

	Thickness. Feet.	To bottom of formation. Feet.
"Big lime"	710	2,150
Clinton sand	35	2,298

These two records show a thickening of the "Big lime" of 10 feet, and a dip of the Clinton sand of 305 feet or 55 feet to the mile. Both were gas wells, the first small, while the second started flowing at the rate of 1,250,000 cubic feet per day.

Three and one-half miles east brings us to Bremen, where the underground succession is well known. Rodafer well No. 13 at edge of village; elevation of well head 800 feet. Authority, Schrier & Kerr:

	Thickness. Feet.	To bottom of formation. Feet.
Mantle rock	40	40
Casing 8 inch, 43 feet.		
Berea sand	25	650
Casing 6½ inch, 655 feet.		
Bedford and Ohio shales	935	1,585
"Big lime"	770	2,355
Heavy flow of water at 2,115 feet	....	2,115
Clinton sand	30	2,488
Bottom of well 2,493 feet.		

Here the "Big lime" is 770 feet thick, an increase of 17 feet to the mile, while the Clinton sand lies 1,658 feet below sea level, an increase of 210 feet or a dip of 60 feet to the mile.

The next record is Welch No. 8, northeast quarter of Section 19, Jackson Township, Perry County, two miles south of Flagdale; elevation of well head 864 feet. Authority, J. J. Klise:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	35	35
Berea sand	40	800
Casing 8¼ inch, 800 feet.		
Bedford and Ohio shales	1,060	1,860
"Big lime"	780	2,640
Casing 6⅝ inch, 2,544 feet.		
Cave from 2,640 to 2,774 feet.		
Clinton sand	31	2,805
Pay rock 2,789 to 2,774 feet.		
Bottom of well, 2,805 feet.		

This well began producing oil at the rate of 25 barrels a day. It is 4 miles east of Bremen and shows an increase of 10 feet in the "Big lime"

and 125 feet in the Bedford and Ohio shales. Wells in this vicinity show that the surface of the Clinton sand is gently rolling, but no relation was found between the elevations and depressions and the production of oil.

The last of this group of records is on the Lefever farm, Section 13 of Pike Township, three miles south of east of New Lexington; elevation of well head 831 feet above ocean level. Authority, J. J. McGonagle:

	Thickness. Feet.	To bottom of formation. Feet.
Conductor	17	17
Flow of water at 62 feet.		
Berea sand	15	960
Casing $6\frac{5}{8}$ inch, 960 feet.		
Bedford and Ohio shales	1,345	2,305
"Big lime"	800	3,105
Heavy flow of water at 2,993 feet.		
Casing $5\frac{3}{16}$ inch, 3,290 feet.		
Shales	195	3,300
Clinton sand	35	3,335

The sand was of poor quality and was without oil or gas. This well is 10 miles east and one mile north of Welch No. 8, and shows a thickening in the Bedford and Ohio shales of 285 feet and in the "Big lime" of 20. The Clinton sand is 2,469 feet below sea level, a drop of 559 or 59 feet to the mile.

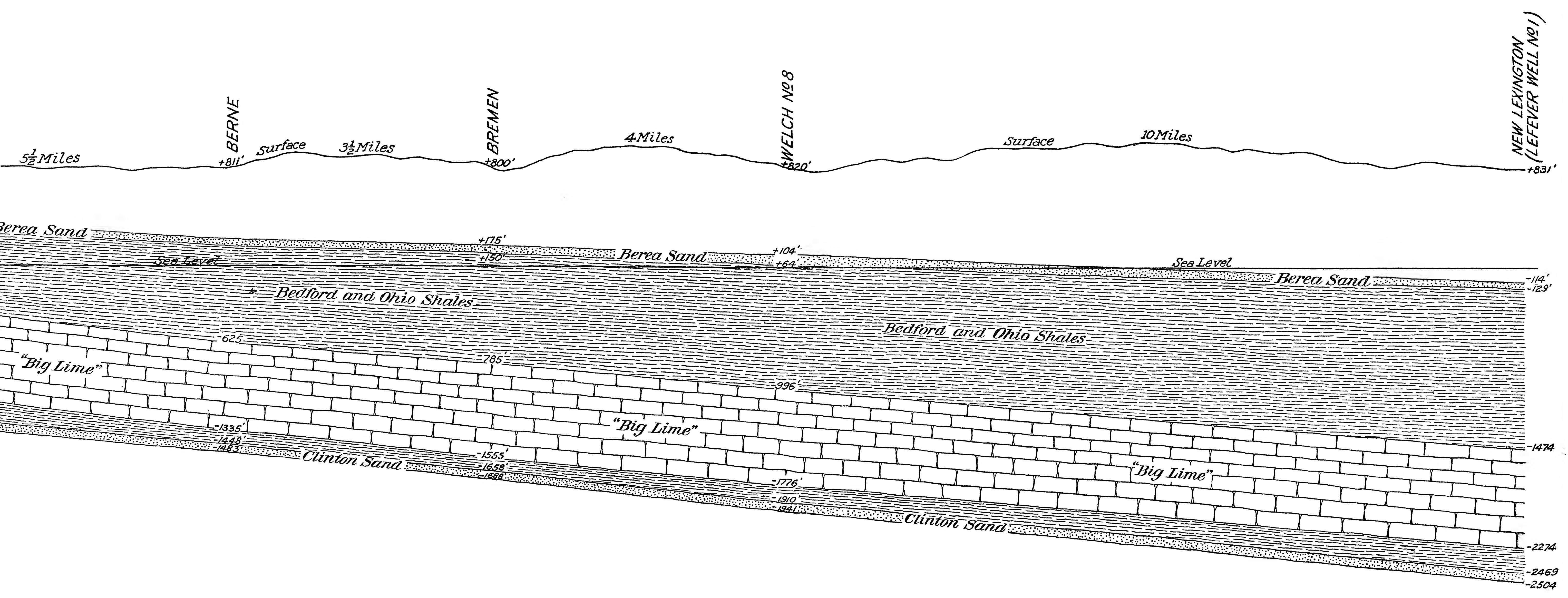
As a summary it may be stated that from Lancaster to the Lefever well southeast of New Lexington, a distance of 23 miles, the Bedford and Ohio shales have increased 715 feet in thickness, an average of 31 feet to the mile; the "Big lime" has thickened 100 feet or more than 4 feet to the mile, and the Clinton sand has dipped 1,326 feet, an average of 57 per mile. It should be noted that the dip of the sand does not vary greatly, as the following summary shows:

Lancaster to Berne	55 feet per mile.
Berne to Bremen	60 feet per mile.
Bremen to Welch No. 8	63 feet per mile.
Welch No. 8 to Lefever No. 1	56 feet per mile.

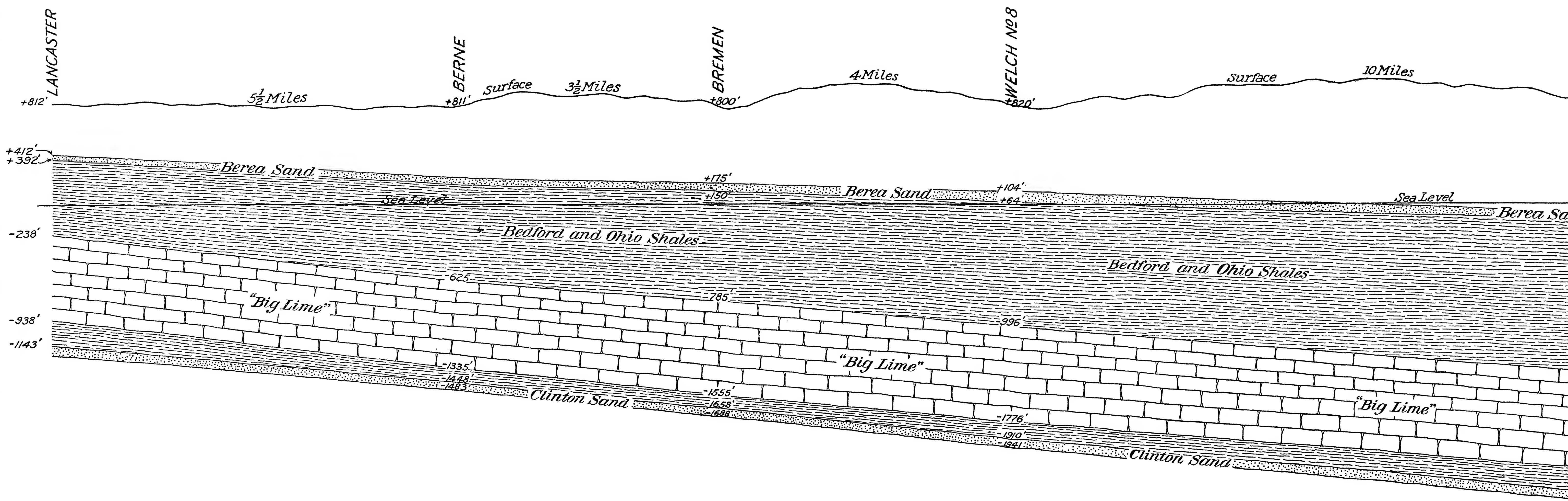
These figures not only do not show an anticline, but the larger dip in the vicinity of Bremen and the Welch well indicates rather the reverse. The structure of the sand may be likened to a very shallow basin tipping to the east and south. Pools usually show low folds with intervening depressions, but oil was found in both places.

Having shown the changes in the principal formations to the east and southeast, a record will next be given of a well in the New Straitsville pool; this is Martin No. 3. Authority, Hon. E. S. Martin:

SECTION FROM LANCASTER EAST TO NEW LEXINGTON



SECTION FROM LANCASTER EAST TO NEW LEXINGTON



		Thickness. Feet.	To bottom of formation. Feet.
Drive pipe		50	50
First water at 75 feet.			
Second water at 380 feet.			
Berea sand		20	940
Bedford shales (red)		60	1,000
Ohio shales	Black, 20 ft; "Little Cinnamon," 30 ft.; "Big Cinnamon," 25 ft.	1,170	2,170
"Big lime"		820	2,990
Clinton sand		17	3,192
Bottom of well 3,213 feet.			

The elevation of this well head was not determined, but that of the Clancey heirs is 760 feet. The oil sand in that was reached at a depth of 3,106 feet and therefore lies 2,346 feet below ocean level. This is a drop of 212 feet from Junction City and 688 feet from Bremen.

The Clinton Sand.—This is unique in that it nowhere outcrops in the State. Not that the associated strata fail to rise to the surface, for they may be seen in a broad belt extending from Preble to Adams Counties in the southwestern part of the State. The sand in question, which nowhere has been reported more than 102 feet thick in Ohio, thins rapidly to the west and disappears before the longitude of the Scioto River is reached. At any rate, no wells that far west have reported the Clinton sand. Wells in such places record nothing but shales between the base of the "Big lime" and the red rock usually called Medina.

The sand has not been reported farther south than Washington Township, Jackson County, but its horizon has not been reached farther south, with the exception of Mt. Vernon and Ironton, Lawrence County, where no sand was found.[1] To the north it has been traced to Lake Erie, and is there a source of gas in commercial quantities. Eastward it has been found in Olmsted Township, Cuyahoga County, and at Wooster. In central Ohio it has not been reported farther east than Muskingum County, and in Crooksville and near Roseville in eastern Perry County. There is no reason to believe however, that the sand is not present farther east, but its depth is such that the drill has not penetrated it. Facts will later be stated concerning the sand in the Vinton, Knox, and Richland County pools, and it remains now to state the record for the Bremen field. Later, the many tests in territory that has not proven a source of oil or gas will be reviewed.

Like most sands, the Clinton has no characteristics that serve to distinguish it from others, and few men with experience would be so rash as to say whether a given hand specimen is Clinton or not. Commonly the color is gray, but the shade may change to brick-red, and both may be a source of oil. Especially is this true near Bremen, but in all directions from that village the red color usually fades away. The rock is commonly fine-grained and compact. Anyone basing his knowledge of oil

[1]Tests have also been made near Oak Hill, Jackson County and Vinton, Gallia County, but neither reported the Clinton sand.

sands on the coarse open-textured varieties represented by the Cow Run and Big Injun would look with scant favor on the Clinton. Wells generally make a poor showing until after being shot, indicating a compact sand.

The sand in the Bremen field is persistent, rarely wanting. Twenty wells selected at random in the Bremen pool showed thicknesses ranging from 4 to 38 feet, with an average of 29 feet. Those in the New Straitsville pool found the sand more uniform, varying from 17 to 38 feet and averaging 27 feet. Wells near Junction City give similar results, and this is true also in the Pleasantville pool.

In no other oil rock in Ohio are similar conditions found with reference to salt water. Generally an oil well pumps several times as much brine as oil, but in the Clinton sand—everywhere in Ohio—the reverse is true. Some of the drillers of wide experience maintain that the rock is free from water and that the little occasionally found has worked down from the "Big lime." Others take the view that the sand in places contains a small quantity of water. Considering the small volume found and that some wells pump none at all, as well as the chances for water to work down around the casing or through leaky joints, leads the writer to the conclusion that the sand is normally free from water when first penetrated by the drill.

The closed or rock pressure of gas wells is commonly regarded as due to the weight of a column of water; that is, to hydrostatic pressure. Occasionally gas wells in the Bremen field register 700 pounds or even more to the square inch, and yet the fuel comes from a formation that is free or nearly so from water and that is imbedded in shales that are impervious. The same is true in the great gas fields of Central Ohio. These facts demonstrate that water is not the cause or even a factor in the rock pressure of gas in the Clinton sand.

The dip of the sand has been indicated on preceding pages and is shown on Plates IV and V. Gas, when found, is nearly always in the higher parts of the formation, that is, along its western border, and oil at greater depth to the east. It is a common theory that oil rests on the surface of salt water and rises or falls with this liquid. That cannot apply in the Bremen field for the reason little or no brine is present, and it is a reasonable assumption that the oil accumulates in the depressions where the Clinton sand is sufficiently open textured to store it.

Shales between the Clinton Sand and the "Big lime".—The position of the oil rock with reference to the "Big lime" varies from pool to pool and to a smaller extent from well to well. In that part of the Bremen pool first drilled, five wells selected at random showed intervals ranging from 113 to 140 feet with an average of 126. In the valley of Rush Creek near Flagdale six wells gave figures varying from 117 to 142 feet, an average of 128. Near the village of Bremen the interval is less, seven wells showing variations from 88 to 115 feet and averaging 103. At New Straitsville, farther south, the interval is notably larger, five wells averaging 171 feet.

This interval is occupied by shales with occasional thin layers of

shaly limestone, known as shells among drillers. A workman of large experience in the Bremen pool gave the succession as follows:

Base of "Big lime"	Feet.
Shales, lead color	55
Shales, green color	30
Shales and shells	20
Shales, red	5
Top of Clinton sand.	

Following is a partial record from a well near Sugar Grove, samples of the drillings having been collected by the writer:[1]

Base of the "Big lime."	Feet.
Shales, light chocolate color; some lime	36
Shales, green and chocolate colors, the latter fossiliferous; some lime	31
Shales, green and chocolate colors; much lime	37
Top of Clinton sand.	

Doubtless the shales vary somewhat in color as in other properties, from well to well. The red band reported in the Bremen pool is quite persistent and is one of the guides to the driller. It has been confused with the red shales lying below the Clinton and commonly known as Medina. In such cases the driller concludes that he has passed the horizon of the desired sand, when in fact he has not reached it.

The "Big lime."—In nearly every oil and gas field some formation or formations exist to serve as a guide to the driller. Thus in the shallow sand territory of Morgan, Noble and Washington Counties, the Ames or Crinoidal and the Cambridge limestones serve in this capacity. Farther east the "Big lime" is the great guide. This name is used for another formation already referred to a score or more times in this bulletin, and it is very important that the two be not confused.

The "Big lime" of southeastern Ohio is the Maxville limestone of this State and the Greenbrier of West Virginia. It forms the summit of the Mississippian (Lower Carboniferous) rocks and hence lies high above the "Big lime" of the Clinton fields which represents the lower part of the Devonian and nearly the whole of the Silurian (Upper Silurian).

The Maxville or "Big lime" attains a maximum thickness of 110 feet in Ohio, but thins rapidly to the northwest and is seldom reported by the driller beyond the middle of Washington and Monroe counties. Occasionally it has a little oil or gas, but the formation is not rated as one of the commercial sources of either of these fuels. Imbedded in rocks, otherwise without limestone, it serves admirably as a guide to the driller. Interesting to report, this formation lies above drainage in parts of Muskingum County and others to the southwest. It was named from Maxville Perry County, where a fine exposure may be seen.

The "Big lime" of the Clinton sand territory lies much lower in the geological column and comprises nearly the whole of the Silurian (Upper

[1]Bownocker, J. A. *Geol. Surv. of Ohio,* Fourth Ser., Bull. I, p. 118.

Silurian) and the lower part of the Devonian. The relative positions of the two "Big limes" are shown below:

Mississippian (Lower Carboniferous)	Maxville limestone	*The "Big lime" of South-eastern Ohio.*
	Logan group	Keener sand. Big Injun sand. Squaw sand.
	Berea sand.	
Devonian	Ohio shales.	
	Delaware limestone	"*Big lime" of the Clinton sand fields.*
	Columbus limestone	
Silurian	Monroe or "Lower Helderberg" limestone	
	Niagara limestone	
	Clinton limestone	

As is well known, the Columbus and Delaware formations outcrop as a narrow strip from Pickaway County north to Lake Erie, while the remaining members of the "Big lime" are found at or near the surface over much the larger part of the western half of the State.

In thickness the formation varies in different parts of Ohio. Its greatest measurement was at Newburg near Cleveland where it is about 1,700 feet, but according to Orton[1] 800 feet of this belongs to the Salina, a formation that is wanting in central and southern Ohio. Westward it thins, measuring 1,325 feet near Avon, Elyria County, and 1,150 feet at Sandusky. Abundant figures and illustrations have already been given to demonstrate its variation in thickness in Central Ohio. Passing south from Lake Erie the formation again thins. It measures 1,100 feet in Jackson Township, Ashland County; 863 feet near Bladensburg, Knox County; 817 feet near Claylick, Licking County; 780 feet at Bremen; 725 feet at Logan; 590 feet in northern Jackson County, and 584 feet at Ironton on the bank of the Ohio River. These facts are shown diagrammatically on Plate VI.

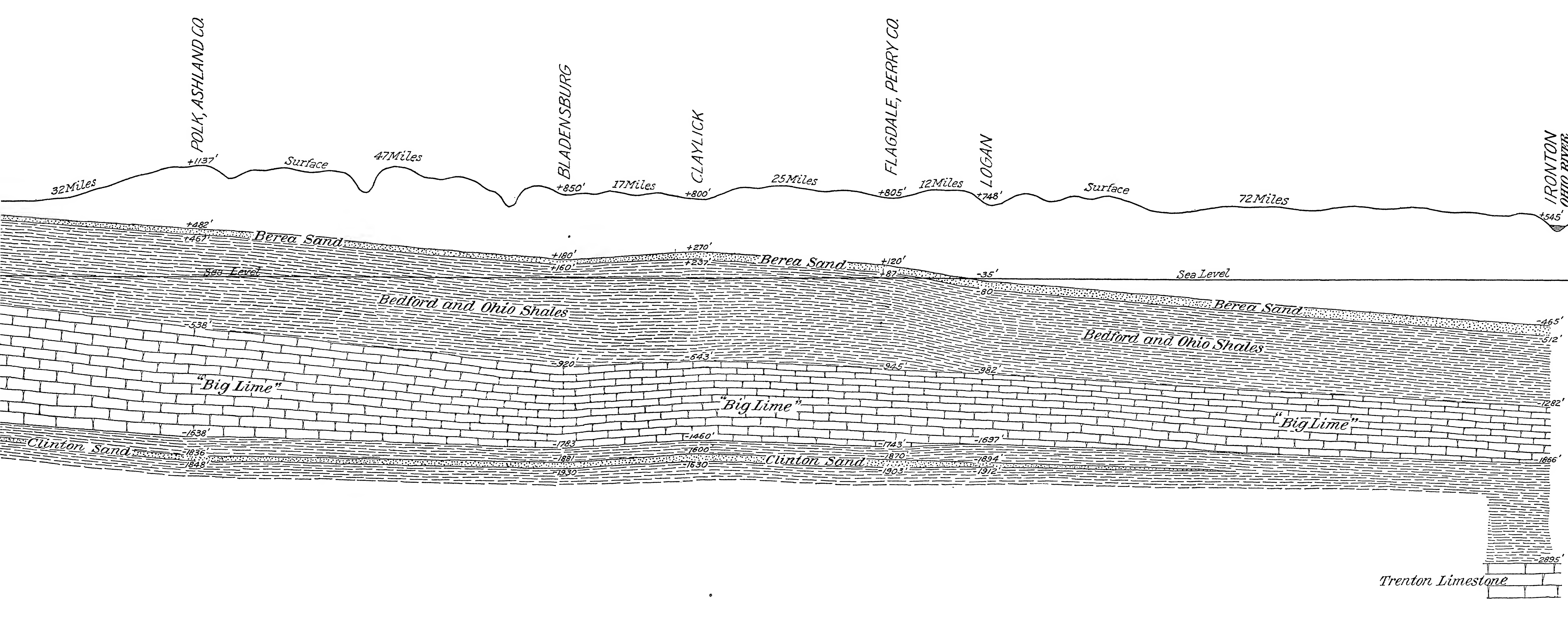
In the Bremen field the "Big lime" is fairly uniform in character. Rarely or never is it broken by shales; in other words, it is a massive formation or rather group of formations, all of limestone. Drillers speak of the top 150 feet as "gritty" and hard to drill. Occasionally it shows a little black oil. Water is found in it at various depths and in varying quantities; near Bremen the heaviest flow is found at about 550 feet. It may fill the hole or when the flow is light may be controlled with the bailer. Where the water is abundant the rock drills easily, indicating a very porous structure. Near its base the "Big lime" is reported of a darker color, softer, and occasionally streaked with shales.

The Survey is indebted to Mr. J. J. McCarten, of Bremen, for an excellent set of drillings from Holliday well No. 8, Section 12, of Rush

[1]Orton. Edward. *Geol. Surv. of Ohio.* Vol. VI, p. 356.

PLATE VI

SECTION FROM LAKE ERIE SOUTH TO THE OHIO RIVER



Creek Township, Fairfield County. Thirty-three of the samples are from the "Big lime," and on the basis of chemical composition and physical properties they may be classified as follows:

Columbus limestone. 50 feet. Calcareous. Gray color.
Monroe limestone. 275 feet. Magnesian. Dark gray color, contrasting in this respect sharply with the Columbus limestone. Some gypsum at from 125 to 200 feet in the formation.
Niagara limestone. 360 feet. Magnesian. Light gray color changing to brown in lower part. Drillings fine, resembling sand grains. These drillings in size and color make a sharp contrast with those of the Monroe limestone.
Clinton limestone. 95 feet. Calcareous. Dark gray at top, changing to various tints below with slate color at base.

In the vicinity of Sugar Grove a layer of sand is occasionally reported in the "Big lime" and may yield a good flow of gas. The same condition has been found in Ashtabula County,[1] while in Lucas County a sandstone in the Monroe limestone ("Lower Helderberg") has long been quarried for making glass. As the "Big lime" is followed north and south from Bremen it shows little change, except in thickness, until the northern counties are reached, when rock salt appears. The latter point will be referred to again in the review of Wayne, Medina and Lorain counties.

The Ohio Shales.—This great formation and the Bedford shales—the latter lying immediately below the Berea sand—occupy the great interval between the latter and the "Big lime." Quite commonly the Bedford has a red color, and then may easily be distinguished from the Ohio shales, but when the color is that of slate, or dark gray, green or black, the usual colors of the Ohio shales, it is difficult or impossible for the driller to determine where the Bedford terminates below. These shales outcrop along the shores of Lake Erie almost as far west as Sandusky, and from there south across the state to the Ohio River. The Ohio shales have been described in our State reports for the past forty years, and nothing more than the salient features will be attempted here. As is well known, they consist of shales only, but along the Ohio River in the eastern part of the State they have been reported, a very few times, to contain a thin bed of sandstone, the western extension of one of the oil bearing rocks of Pennsylvania. Their color varies from dark gray, through green to black, and the texture is that of clay. In other words, they are composed of aluminous particles rather than sand. Their composition varies rapidly, horizontally as well as vertically, and this has operated against their use in the manufacture of clay products. Concretions of various kinds are abundant, and constitute the most important structural feature of the formation. The most striking feature, however, to the driller for oil or gas has already been specifically pointed out, and will simply be mentioned here; the shales thicken to the east and south, and hence increase the interval between the Berea sand and

[1] Bownocker, J. A. *Geol. Surv. of Ohio*, Fourth Ser., Bull. I, p. 303.

the "Big lime." At McConnelsville, on the Muskingum River, they measure 1,739 feet. The variations from the lake to Ironton have already been shown on Plate VI, and further consideration of that matter will not be given here.

The importance of these variations and those of the "Big lime" are of the first grade to the driller. It increases the dip of the Clinton sand, and hence its depth, limiting the territory in which it is accessible. Along the Ohio River in eastern Ohio, the shales may be 3,000 feet thick, and manifestly the Clinton sand is at such a depth that it cannot be a commercial source of fuel. In the vicinity of Zanesville this formation is reached at a depth of 3,543 feet,[1] and in the writer's judgment this is about the maximum depth to which drilling will extend in Ohio under existing conditions.

The Ohio shales have long been a source of gas along the lake shore. Usually a well supplies heat and light for a residence, and occasionally for several, but the supply is never large. The gas is not found at any one horizon, and hence the depth varies. In central Ohio the shales contain less fuel, and these are not a source of gas in a commercial way. In Pennsylvania this great formation contains a number of important oil and gas rocks, such as the Bradford, McDonald and Gordon sands. Westward these thin and disappear, or practically so, by the time the Ohio River is reached. Many wells for one or the other have been sunk in eastern Ohio, but the result in every case has been failure.

The Berea Sand.—This is the last formation in the ascending column that will be considered, and only a few sentences will be given to it. The formation outcrops in much the same way and places as the Ohio shales. It is very persistent, and has been penetrated by the drill in every county where due, and in many of them scores of times. Well records already given and those which follow show its thickness in many counties. Farther east and south it is thinner, but nearly always present. As is well known, it is a valuable source of oil and gas in Jefferson, Belmont, Washington, Perry and other counties, and in eastern Ohio is the lowest available source of these fuels.

Formations Below the Clinton Sand—These are well shown for this part of the state by the following well record: Crouse Well No. 1, Section 32, Pleasant Township, Fairfield County; completed August 19, 1907. Authority, B. S. Stretton:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	41	41
Casing 6½ inch, 605 feet.		
"Big lime" top at 1,378 feet.		
Casing 5 inch, 2,044 feet.		
Clinton sand	5	2,185

[1]For well record see p. 35.

		Thickness. Feet.	To bottom of formation. Feet.
Medina (?) shales.	red .... 8 feet.	284	2,500
	blue .... 76 feet.		
	pale red .... 90 feet.		
	green .... 40 feet.		
	red .... 70 feet.		
	blue .... 75 feet.	970	3,470
	slate and shells ......100 feet.		
	white shells .... 90 feet.		
	dark .... 28 feet.		
	shells .... 90 feet.		
	harder shales ....121 feet.		
	black shells .... 35 feet.		
	white shells .... 12 feet.		
	dark shells .... 27 feet.		
Ordovician shales.	blue at ....2,224 feet...	207	3,470
	pale red at ....2,300 feet.		
	green at ....2,390 feet.		
	red at ....2,430 feet.		
	blue at ....2,500 feet.		
	slate and shells (100 ft.) ....2,575 feet.		
	white shells at .....2,675 feet.		
	green at ....2,765 feet.		
	dark at ....3,078 feet.		
	shells at ....3,106 feet.		
	shells at ....3,196 feet.		
	black shells ....3,396 feet.		
	light shells at .....3431 feet..		

Trenton limestone at 3,470 feet.
Bottom of well at 3,569 feet.

This shows an interval of 1,285 feet between the Clinton and Trenton. At Amanda, approximately ten miles to the southwest, the same interval measures 1,193 feet. Persons desiring the thickness of the Trenton and information on the formations below it should consult the record of the test at Waverly on page 48.

METHOD OF DRILLING.

This varies but little from other deep sand territory in the Appalachian field. At first the wells were drilled "wet"—that is, casing was inserted at the base of the Berea, and none other was used until the Clinton sand was reached. As already stated, heavy flows of brine were found in the "Big lime," especially at from 500 to 600 feet in that formation, and that greatly retarded the progress of the drill by its buoyant action on the hemp cable. This objection, however, was later overcome by using a wire cable in place of hemp from the water down. At present the casing is hung on a disc packer which is usually set just below the place of the heavy flow. In other words, the casing is hung in the well rather than placed on the Clinton sand. The long column of water may crowd the oil away from the hole, thus diminishing the production, and may enter the sand, producing possible evil effects.

These difficulties may be overcome by drilling "dry." In this method casing is set just below the Berea, and another string below the heavy flow of water in the "Big lime." Sometimes several flows are found and it may be necessary to recase each time, adding materially to the labor. Worse still, the shales lying above the Clinton sand cave badly, necessitating a liner between that formation and the base of the "Big lime." This increases the difficulty in shooting, for when the shot is placed and the liner drawn, a cave follows and may cause difficulty in discharging the shot. This is usually met by placing a loaded anchor of such length that it extends above the cave. Perhaps one-half of the wells in the Bremen field have been drilled "dry." In drilling "wet" little or no cave takes place, the weight of water apparently keeping the shales in position.

In this method hemp cables are used, but when drilling "wet" wire replaces the hemp as soon as a heavy flow of water is found in the "Big lime." Friction with the rough walls of the hole soon destroys this cable, but the pieces may later be used in pumping wells. Derricks 80 feet high are used. Nearly all are wood, but steel has made its appearance and may be the reliance of the driller in the future. It is more expensive, the cost being about $900 against $725 for wood.

The expense and time necessary for drilling a producing well naturally varies with the depth and the freedom from accidents. For the territory in the valley at Bremen it is about as follows:

Derrick (wooden)	$725
Drilling 2,450 feet at $1.10	2,695
Conductor 80 feet at 70 cents	56
Casing to base of Berea 650 feet at 55 cents	358
Casing to Clinton, 2,450 feet at 45 cents	1,102
Tubing 2,460 feet at 15 cents	369
Pumping outfit	250
Gas engine and belt for pumping	850
Two tanks	225
Tank house	100
Lead lines, etc	100
Total	$6,830

If the well is dry the expense is approximately as follows:

Drilling	$2,698
Moving rig	200
Conductor	56
Total	$2,951

It will be noted that allowance is not made here for the wear and tear on materials used. This will increase the expense to about $3,500. With good luck, such a well may be completed in 30 days from the time drilling begins.

CHAPTER II.

THE SEARCH FOR THE CLINTON SAND EAST AND SOUTH OF THE BREMEN FIELD.

The search for the Clinton sand in Southern Ohio has been in progress twenty years. The formation has not been found farther south than Jackson County, though tests have extended to the bank of the Ohio River.

PERRY COUNTY.

Many tests of the Clinton sand have been made in this county with the hope of extending the Bremen field, and while these in the main have been unsuccessful, they have occasionally found the desired fuel and may lead to important extensions.

Monday Creek Township.—About a score of Clinton wells have been drilled in this township, with but little success. The following record of the Perrill well at Maxville shows the succession of the important strata as far down as the Clinton:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	27	27
Fresh water at 250 feet.		
Berea sand	25	830
Casing 6½ inch, 840 feet.		
Bedford and Ohio shales	1,128	1,958
"Big lime"	810	2,768
Gas at 2,426 feet.		
Water at 2,442 feet.		
Clinton sand	33	2,973
Bottom of well 2,984 feet.		

This well was completed in July, 1909, and is reported to have begun producing 40 barrels of oil a day, and a year later about one-fourth as much.

The Columbus Hocking Coal & Iron Company has drilled a number of wells. One on the southeast quarter of Section 22 gave a moderate flow of gas which is piped four miles to Kachelmacher's brick yard and used in burning brick. Another well, drilled a few hundred feet to the south, was dry. The company drilled also in the southwestern corner of Section 11, but found only a shell of the desired sand; a depth of 3,565 feet was reached. A well in the southeastern corner of Section 13 was dry.

Other wells were drilled in this township as follows: a small oil well and a dry hole on the southeastern quarter of Section 4, and a dry

hole along the western border of the section; two dry holes on Section 5, one on the southeastern quarter, and dry, and one near the northern line of the section, the latter making a showing of oil; a small oil well and a dry hole on Section 7, the former on the northwestern quarter and the latter on the southeastern; a dry hole on the northwestern quarter of Section 8; two wells on Section 9, an oil well that started at about 30 barrels on the northeastern quarter and a dry hole on the southeastern; a dry hole on the northwestern quarter of Section 10; a dry hole drilled by the Carter Oil Company on the northeastern quarter of Section 19, and a small oil well, drilled by the same company, and now abandoned on the same quarter of Section 20.

Salt Lick Township.—But one well has been drilled in this township, and that was about one-half mile west of McCuneville. The elevation of the well head is 797 feet above ocean level. The well was drilled by the Shawnee Oil & Gas Company, and the record, as furnished by L. C. Laube, may be found on page 20.

At 1,510 feet the drill struck a sandstone about one foot thick which contained a heavy black oil. The sand was shot with 8 quarts and the well pumped; it yielded five barrels the first day, three the second and then two a day for approximately two weeks. The driller calls this sand the Gordon. It lies in the Ohio shales and is probably of local extent only; at any rate it has not been reported elsewhere in Ohio. Not satisfied with the production, the tubing was drawn and the drill started for the Clinton. Work progressed favorably until the "Big water" was reached at 2,756 feet. Casing was inserted at about 2,800, and after pumping 2,600 feet of water from this, the hole was dry until 20 feet advance was made, when another heavy flow was encountered and the well filled to within 20 feet of the top. Again the casing was set and drilling resumed. Seven additional times heavy flows of water were found, and each time the casing was reset. The last flow was only 6 feet above the base of the "Big lime," and the casing was finally set 8 feet below the base of that formation. To add to the trouble the packer broke twice, necessitating drawing the casing each time, making 10 changes in all.

At a depth of 3,070 feet the well began caving and of course this delayed the work, but the liner was finally set on top of the Clinton sand. This formation was 32 feet thick and varied somewhat in color as follows:

	Feet.
Gray sand	12
White sand	1½
Pink sand	5
Lighter colored sand, gray near the bottom	13½

The next step was to shoot the well, for the sand made a showing of oil. Fifty quarts of nitroglycerine increased the production to such

an extent that the bailer came up filled with the fluid and it was decided to shoot again. Accordingly a dump shot of 200 quarts and 100 feet of loaded anchor were placed in the well. The liner was then withdrawn, and after two unsuccessful efforts to discharge the shot, the line was run and a bridge found about 30 feet above the top of the anchor. On the following day the driller ran down the tools to remove the bridge, and after about ten minutes' work it gave way and discharged the shot. The tools were blown up about 300 feet in the hole and torn loose from the cable, but were removed without great difficulty. Next an effort was made to clean the well. As soon as the bottom of the casing was reached, water again appeared and could not be controlled. Thinking that the casing was leaking, it was again withdrawn, but found to be all right. Apparently the shoulder of Clinton sand on which it rested had been partly blown away, letting the water flow in below. Not knowing what to do, and completely discouraged, "the company plugged the hole, drew the casing, and quit."

Considering the large sum of money already expended, it may be asked if it would not have been worth while to try developing a new shoulder for the casing to rest on, after the manner in California. The hole could have been filled with cement to a little above the Clinton sand, and after setting redrilled, and the casing placed on top of the new shoulder. The expense of this experiment would have been small, and might have saved the well.

Pleasant Township.—At least two Clinton wells have been sunk in this township. In the spring of 1909 one was drilled on the McGonagle farm a half mile south of Moxahala. The well head was 832 feet above ocean level, and the Clinton sand was found 52 feet thick, but it contained not even a smell of oil or gas. About a year later the Penn Oil Company, of Pittsburg, drilled a well two miles south of Moxahala, on land of James Kelly, but it, too, was a failure.

This sand is remarkable for its thickness, 102 feet. So far as the writer knows, it is far and away the greatest yet reported for the Clinton in Ohio, and it is twice the usual maximum given. The sand is also notable for its coloring. In spite of the great quantity, it did not contain a trace of either oil or gas. Neither did the sand contain water, while the "Big lime" had so little that no casing was used below the Berea.

Harrison Township.—The survey has record of three Clinton wells in this township, which lies along the eastern edge of the county, and all produce oil or gas. They are the deepest successful wells yet drilled in Ohio. On November 10, 1909, a well was started on the farm of David Allen, Section 8 of Harrison Township, about two miles southwest of Roseville, and progress was such that the well was not completed until March 29, 1910. The well was drilled by Stretton & Cole, who have provided the following record:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe 10 inch	40	40
Casing 8 inch, 550 feet.		
Casing 6½ inch, 920 feet.		
"Big lime"	955	3,280
Casing $5\frac{3}{16}$ inch, 3,240 feet.		
Clinton sand	44	3,476
Oil at 3,470 feet.		
Total depth 3,439 feet.		

This well started pumping about 15 barrels a day. though some have reported the rate as high as 25 barrels. When visited in July, 1910, it was out of order, and, in fact, does not seem to have been properly cared for. It is the deepest oil well in Ohio, and one of the deepest in this country.

A well was completed by the Ohio Fuel Supply Company in the valley at Crooksville in October, 1909, and is reported to have started producing gas at the rate of 2,000,000 cubic feet a day. Later an overflow of the creek flooded the well, and it had not been put in condition by July, 1910. The Clinton sand, 28 feet thick, was struck at 3,409. January 5, 1910, a well was completed by the same company one location from the above, and began producing ten barrels of oil a day, and six months later was making 15 barrels. The well was shot first with 60 quarts, and later with 200. When agitated it still flows (July 16, 1910). The well head is 760 feet above ocean level, and the Clinton sand was struck at a depth of 3,407. The sand is 54 feet deep; it contained a break at 3,422 feet, and 14 feet of pay beginning at 3,444.

A location has been made by the Sago Oil Company near the edge of the corporation, and probably by the time these lines are in print a third will have been drilled to the Clinton sand. To be profitable such wells must be at least fairly large, long-lived and dry holes few.

Reading Township.—This lies north of Jackson, one of the largest producers in the entire Bremen field, and has been tested at numerous places. In the northwest quarter of Section 32, seven wells have been drilled, of which three produce oil. In the southern half of Section 35, out of five wells drilled two oil producers were gotten. On land of the St. Joseph's Literary Society four gas wells have been secured in the southwestern quarter of Section 14. Well No. 2 on this property gave measurements as follows, the head being 1,025 feet above ocean level:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	30	30
Berea sand	75	1,015
Casing $6\frac{5}{8}$ inch, 1,060 feet.		
Bedford and Ohio shales	1,100	2,115
"Big lime"	817	2,932
Clinton { sand 34 feet; shale 5 feet; sand 20 feet }	59	3,128
Bottom of well at 3,130 feet.		

Occasionally a small oil or gas well has been secured elsewhere in the township, but the usual result has been a dry hole. The location of these is shown on Plate I.

The Northern Tier of Townships.—Less exploration has been done in these townships than farther south, and little has been found to reward the driller. About three years ago seven wells were drilled in the northwestern corner of Thorn Township, the result being three small gas wells and four dry holes. The following measurements are from the John Trovinger Well No. 1, on the southeastern quarter of Section 8:

	Thickness. Feet.	To bottom of formation. Feet.
"Big lime"	710	2,320
Clinton sand	20	2,480
Bottom of well 2,570 feet.		

Four wells are reported from Hopewell Township. One along the eastern line of Section 11 produced some oil, but the well has been abandoned. The other tests were as follows: A dry hole along the eastern border of Section 17; a dry hole on the eastern side of Section 12 and one on the southeastern quarter of Section 24.

The only test of which the Survey has knowledge in Madison Township is on the southwestern quarter of Section 5. A flow of gas was secured, but apparently the result has not encouraged further drilling.

MUSKINGUM COUNTY.

Several Clinton wells have been drilled in this county, the first attempt having been made in 1884 following the excitement from the discovery at Findlay. The location was at Zanesville and a depth of 2,000 feet reached, but the Berea was without oil or gas and the drill did not even approach the horizon of the Clinton sand.

In 1903 The Chicago-Zanesville Oil & Gas Company made a test at Dillon's Falls in the valley of the Licking River a few miles above Zanesville, the record of which follows:

	Thickness. Feet.	To bottom of formation. Feet.
Berea sand	12	907
Bedford shales	21	928
Ohio shales	1,192	2,120
"Big lime" { limestone 160 feet; black shales 68 feet; limestone 1,047 feet }	1,275	3,395
Shales	88	3,483
Lime shell	6	3,489
Shales	11	3,500
Sandstone	3	3,503
Shales	12	3,515
Lime shell	7	3,522
Shales	21	3,543
Clinton sand	21	3,564
Blue shales	3	3,567

Small flows of salt water were struck at 2,560 and 3,205 feet, and a show of oil and gas in the Clinton at 3,562; the well was abandoned.

Quite recently three wells have been drilled on Sections 18 and 19 of Newton Township, near the village Fultonham, two of which produce oil and one gas. The latter is on land of W. J. Roberts, Section 18, and the former on farms of Mary E. Grimsley and Emily Moore, Section 19. The Grimsley well started producing 7 barrels per day, but after having been shot with 60 quarts increased to approximately 20 barrels. At date of writing the Moore well has not been completed and its production cannot be stated. Following is a record of the Roberts well:

	Thickness. Feet.	To bottom of formation. Feet.
Limestone	54	96
Shale	5	101
Limestone	19	120
Water at 75 feet.		
Sandstone	130	250
Limestone	38	288
Much water at 270 feet.		
Big Injun sand	224	512
Limestone	98	610
Berea sandstone	14	861
Water in Berea sand.		
Bedford shales	26	887
Casing 882 feet.		
Ohio shales	1,308	2,195
"Big lime"	970	3,165
Casing $5\frac{3}{16}$ inch, 3,003 feet.		
Limestone shell	8	3,282
Clinton sand at 3,296 feet.		
Gas at 3,298.		
Total depth 3,314 feet.		

On May 21, 1909, the Zanesville Gas & Oil Company completed a well on the farm of George Handchsy, Section 25 of Perry Township, six miles east of Zanesville. The Clinton sand was struck at 3,705 feet and though 38 feet thick it did not contain a trace of oil or gas. For the following record of this well the survey is indebted to Mr. W. Hunter Atha of Zanesville.:

	Thickness. Feet.	To bottom of formation. Feet.
Berea sand	23	1,033
Bedford shales (red)	15	1,048
Casing 6 inch, 1,065 feet.		
Ohio shales: limestone 15 feet; shale and lime shells 1,312 feet; lime shells 265 feet	1,592	2,640
"Big lime"	1,005	3,645
Much water at 3,486 and 3,544 feet.		
Casing 5 inch, 3,553 feet.		

	Thickness. Feet.	To bottom of formation. Feet.
Black shales	5	3,650
Lime shells	3	3,653
Shales	16	3,669
Sand shells	3	3,672
Shales	18	3,690
Red sandstone	4	3,694
Black shale	15	3,709
Clinton sand	38	3,747
Shales	58	3,805

In the autumn of 1910 two wells were being drilled in the northwestern part of the county, one in Jackson Township about three miles northwest of Frazeysburg, and one in Muskingum Township about two miles southeast of the hamlet Shannon.

In October, 1910, a well was completed on the Fairall land in the southwest quarter of Section 7 of Jackson Township, the record of which follows:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	28	28
Berea sand	16	850
Casing 6⅝ inch, 863 feet.		
Bedford and Ohio shales	1,185	2,035
"Big lime"	934	2,969
Casing 5$\frac{3}{16}$ inch, 2,844 feet.		
Shales	172	3,141
Clinton sand	21	3,160
Shales	24	3,194
Total depth of well 3,194 feet.		

This well is rated among the successful producers of oil, though its capacity has not been learned. A test is now being made in the northwestern quarter of Muskingum Township, but it has not reached the horizon of the Clinton sand.

While tests have thus far disclosed but little oil or gas in this county, they have proven the Clinton sand present in good thickness at widely separated intervals, and with this encouragement further drilling is certain.

MORGAN COUNTY.

In September, 1894, a deep well was begun at McConnelsville, the town council having provided $5,000 to meet the expense. Progress was slow. By the middle of the next March a depth of 3,186 feet was reached, and the tools having become fast the well was abandoned. Following is a record of this well:[1]

[1]For a detailed record see Bownocker, J. A. *Geol. Surv. of Ohio* Fourth Ser., Bull. I, p. 145.

	Thickness. Feet.	To bottom of formation. Feet.
Surface materials	15	15
Shales, sandstones, clay and coal	610	625
Maxville limestone or "Big lime"	44	669
Keener sand	40	709
Big Injun sand	45	840
Cuyahoga shales	409	1,249
Sunbury (Berea) shales	30	1,279
Berea sand	66	1,345
Bedford sandstone and shales	25	1,370
Ohio shales	1,712	3,082

"Big lime" at 3,082 feet.
Bottom of well in "Big lime" at 3,186 feet.

As the record shows, the drill stopped far short of the Clinton, and while it was a failure so far as its object was concerned, it performed a useful service to geology by providing additional information on the deeper formations in this part of Ohio. The point of most interest is the great thickness of the Ohio shales, a fact already referred to in this report and in previous ones.

Only one well in the county has reached the Clinton sand, and that was on land of T. J. Chappalear in the southwestern corner of Union Township. The well was located on Bloody Run about three-fourths of a mile above the old Blackburn P.O., near the northern margin of Section 32. The altitude of the well head was 750 feet, and was not far from the horizon of the Cambridge limestone. Both this and the Ames limestone are well shown in the vicinity. Mr. J. P. Fishel, the contractor, has furnished the following data from the driller's record:

	Thickness. Feet.	To bottom of formation. Feet.
Berea sand	20	1,170
Bedford and Ohio shales	1,530	2,700
"Big lime"	900	3,600
Clinton sand	9	3,944

Bottom of well in red rock at 3,947 feet.

Not a smell of oil or gas was found. The "Big lime" yielded only about a bailer of water an hour, and it was not necessary to case in it. The geological fact of most interest is the great distance between the "Big lime" and the Clinton, 335 feet. At Bremen this interval measures only 103 feet, but at New Straitsville it has increased to 171.

HOCKING COUNTY.

The west central part of this county contains an important part of the great Sugar Grove gas field, but that does not fall within the scope of this discussion. On the eastern side of the county a number of Clinton wells have been drilled and these will now be considered:

Falls Township.—The county seat, Logan, is in this township. Naturally its citizens viewed with admiration the discovery in large quantity of gaseous fuel at Lancaster and vicinity, and as early as 1890 drilled a test well. This was on North Walnut Street, the elevation of the well head having been about 748 feet. For the following log the survey is indebted to Mr. A. Magoon:

	Thickness. Feet.	To bottom of formation. Feet.
Drift	40	40
Logan sandstone	170	210
Cuyahoga shales	439	649
Sunbury (Berea) shales	34	683
Berea sand	45	728
Bedford shales	85	813
Ohio shales	902	1,715
"Big limes" { Devonian 75 feet; Monroe 300 feet; Niagara and Clinton 340 feet }	715	2,430
Shales	197	2,627
Clinton sand	18	2,645
Total depth 2,694 feet.		

To an unusual degree this gives the formations and their thicknesses, and may be taken as representative for that section of the State. In one or two places the writer has made slight changes in the names, making them conform with the nomenclature in present usage. The shales between the "Big lime" and Clinton sand are left without a name, though Mr. Magoon called them Niagara. According to the writer's interpretation the base of the "Big lime" is represented by the Clinton limestone, and the shales lying beneath it could not therefore be the Niagara.

Not satisfied with this failure, another well was drilled to the Clinton, the location being on the western edge of the town, but a show of gas was the only reward. Some years ago a well was drilled at Enterprise in the northwestern corner of the township. The Clinton sand was found and made a showing of oil, but the well was abandoned. Later a hole was drilled on the Hensel farm, southeast quarter of Section 27, where the following record was made:

	Thickness. Feet.	To bottom of formation. Feet.
Berea sand	40	680
Bedford and Ohio shales	978	1,658
"Big lime"	737	2,395
Clinton sand	22	2,584

A flow of gas was secured at 512 feet in sand in the "Big lime." The Clinton was much broken and without anything in commercial quantities, and the well was abandoned. Two holes have been drilled in the southwestern corner of the township, one on Section 30 and the other on Section 31; both were failures.

Marion Township.—This is the northernmost township of the county. It lies south of Rush Creek of Fairfield which contains important deposits of both oil and gas, and of course has been well tested. Along the western edge a number of gas wells were secured some years ago, but most of them have been abandoned.

Quite recently a test was made on the farm of H. R. Bending, northeast quarter of Section 25. For the following record of this the Survey is indebted to J. P. Bebout, county surveyor; elevation of well head, 983 feet.

	Thickness. Feet.	To bottom of formation. Feet.
Berea sand	35	950
Casing 6⅝ inch, 982 feet.		
Bedford and Ohio shales	990	1,940
"Big lime" at 1,940 feet.		
Clinton sand	26	2,941
Green shales	30	2,971
Limestone	20	2,991
Red shales	8	2,999
Limestone	0⅔	2,999⅔
Blue shales	13	3,012⅔

After shooting, the well caved badly and has not been cleaned, though it made a little oil. The casing and a string of tools rest in it. Other tests of the Clinton sand have been made as follows: northeast quarter of Section 4; southeast quarter of Sections 9 and 10; along the southern edge of 11, and northeast quarter of Section 21. None of these found the sand with anything better than a showing of oil or gas.

Falls Gore Township.—Within the past year or two a number of tests have been made in this township. One on Section 30 yielded some oil, and, encouraged by this, a well was drilled in the spring of 1910 on the Terrell farm nearby, where the following succession was found:

	Thickness. Feet.	To bottom of formation. Feet.
Big Injun sand	190	290
Berea sand at 726 feet.		
"Big lime"	720	2,560
Clinton sand	22	2,801
Bottom of well 2,838 feet.		

After shooting, this well began flowing between 10 and 20 barrels of oil a day.

About the time that the above wells were being sunk, the drill was busy near Gore on the eastern side of the township. In the autumn of 1909 one was completed on the Lemon farm in the southwestern quarter of Section 25, and the Clinton sand, 26 feet thick, was found

at 2,987½ feet. After shooting with 40 quarts of nitroglycerine, the well caved badly and has not been cleaned. It flowed as high as 63 barrels of oil a day, and in July, 1910, was pumping about 25 barrels.

Early in September, 1910, a well was completed on the Williams farm, Section 33, about a mile west of Gore, and 26 feet of Clinton sand found, the top at 2,866. The well has not been connected with the pipe line and its capacity cannot be accurately stated, but it will not be far from 25 barrels.

Green Township.—In 1888, when the excitement about natural gas was high, a deep well was drilled at Haydenville with the hope of securing that fuel for use in the clay industries. The first well found the Berea sand at 788 feet which yielded 100,000 cubic feet of gas per 24 hours. A second well was soon begun, but found that sand without fuel of any kind, and it was decided to continue to the Clinton which was then giving such fine results farther north. A record of this well provided by Mr. J. W. Jones, of Logan, follows. Its elevation above sea level was very nearly 710 feet.

	Thickness. Feet.	To bottom of formation. Feet.
Maxville limestone	8	39
Sandstones, shales and conglomerate	306	345
Large flow of salt water at 250 feet.		
Cuyahoga and Sunbury shales	443	788
Berea sand	44	832
Bedford and Ohio shales	1,108	1,940
"Big lime"	800	2,740
Shales	145	2,885
Red and green shales	33	2,918
Clinton sand	12	2,930

The well did not show either oil or gas.

Sandstone in the "Big Lime."—In Sections 21 and 22 and probably others of Laurel Township a layer of sandstone, with a maximum reported thickness of 40 feet, is found in the "Big lime," and occasionally yields oil and gas. The oil is dark and heavy and is rarely in commercial quantities, but the gas wells are occasionally valuable. The same general condition holds in Falls and Falls Gore townships. This sand is found also in Berne Township of Fairfield County, but has not been reported in the Bremen field.

ATHENS COUNTY.

So far as the writer knows only one Clinton well has been drilled in this county. This was at Buchtel in York Township and was sunk by the Columbus Hocking Coal & Iron Company. No further information is at hand beyond the fact the well yielded neither oil nor gas in commercial quantities.

VINTON COUNTY.

A large amount of exploration has been done in the Clinton sand of this county for oil or gas, but primarily the former. The measure of success has been small for both. For the benefit of seekers after these fuels the tests and their results will be reviewed briefly here.

Jackson Township.—This is the only township in the county that has yielded Clinton oil in commercial quantities. As already stated, the first well was completed in August, 1899. By September, 1902, five oil wells, one gas well and three dry holes had been drilled. Nearly all of these lie in Sections 3 and 4, along the Vinton-Hocking line. These wells are now the property of the Southern Ohio Oil Company. Two new wells were drilled near these in 1909 and small producers secured. These belong to the Locust Grove Ridge Oil & Gas Company. Dry holes nearly surround the pool and important extensions need not be expected. In all about 12 wells have been sunk to the Clinton in this township.

Early wells ranged in production from 10 to 70 barrels per day, later ones being smaller. In the late spring of 1902 the four producing wells then completed were yielding 125 barrels a day. By the following September the production from five wells had dropped to 109 barrels and in July, 1910, to 12 barrels or less, one well alone producing nearly one-half of this. At the same time the two wells drilled in 1909 were making 7 barrels per day. The gas pressure is strong with the result that an occasional flow of oil still takes place. The oil has a density of 47½° Beaume and a green color, but when viewed in small quantity with transmitted light its color is amber.[1] At first the oil was pumped to Orland on the Hocking Valley Railroad and then shipped in tank cars. Later the line was extended to Joy and this method of shipping is still followed.

The producing sand is quite spotted, and this increases the hazard of drilling, but it is soft, and consequently the wells seldom require shooting. Commonly the "pay" has the color of brown sugar, but sometimes it changes to red-brown. Little or no water exists in the sand, and when the pool was visited in July, 1910, no well was reported making as much as one barrel of water a day, and the largest oil well no water at all.

Following is a skeleton record of Clinton Well No. 1, whose altitude above sea-level is approximately 875 feet.

	Thickness. Feet.	To bottom of formation. Feet.
Berea sand	45	750
"Big lime"	700	2,270
Heavy flow of brine at 2,010 feet.		
Clinton sand	15	2,443
Bottom of well 2,449.		

[1]For analysis of oil see p. 17.

Richland Township.—This lies south of Jackson, and has at least six wells to the Clinton. The first of these was drilled early, probably in 1898, but may not have reached the sand. It was located on the east side of Section 4, but gave neither oil nor gas. A little later a well was drilled on land of William Poland, in Section 28. The Clinton was found at approximately 2,340 feet, and gave a heavy flow of gas, which is still used. Encouraged by this result, two additional wells have been sunk on this section, but were failures.

A test has been made on the Wyatt land, near the center of Section 10, but was a failure. The Clinton was reported about 11 feet thick, with a little gas in the top and near the bottom. About 1902 or 1903 a well was drilled on the John Bethel land in the northern part of Section 21; the Clinton, 14 feet thick, was found at 2,377 feet, but was without oil or gas. About the same time a well was drilled on the Radcliffe farm, in the southeastern quarter of Section 6, in the northwestern corner of the township. The "Big lime" was struck at 1,264 feet and the bottom at 1,855. Fifty feet of Clinton sand were found, the top at 2,080. Neither oil nor gas was present in the sand, but a little dark, heavy oil was found in the "Big lime," which was bailed out, but was not renewed.

Swan Township.—This contains a number of deep wells. The first was located on the Cradlebaugh land, about one mile south of Orland, and was drilled in 1901. The Clinton sand was found at a depth of about 2,900 feet, and contained gas. The rock pressure was at least 800 pounds to the square inch, but the open flow was disappointing, being only about 400,000 cubic feet per day. In the following year a well was drilled on the Wadsworth farm, about one-half mile north of the last one. The Clinton sand, in good quality, was found at a depth of 2,811 feet, but was entirely dry.

Near the center of Section 2, on the E. H. Waller farm, the Clinton gave nothing better than a show of gas. On land of George Schurtz, near the middle of Section 15, a little more gas was found, but not enough to warrant tubing. A well on the northwest quarter of Section 14 was dry, and the same is true of one on the northeast quarter of Section 29. No data are at hand with reference to the depth of these, the nature or thickness of the sand. Several wells have been drilled for gas with favorable results near the middle of the western edge of the township.

Clinton Township.—Only one Clinton well is reported in this township. This is on the farm of I. N. Bay, and was drilled in 1910. The Clinton is reported as having been found at between 2,600 and 2,700 feet, but was dry.

Vinton Township.—In 1909 a well was completed on land of Vinton Cattrell, in Section 13, the well head being about 613 feet above

sea level. The "Big lime", 900 feet thick, was struck at 2,160 feet, and ten feet of Clinton sand at 3,210 feet. A depth of 3,268 feet was reached, but neither oil nor gas was secured. For these brief facts the Survey is indebted to Mr. E. F. Clagett, of Columbus.

GALLIA COUNTY.

About the year 1898 a well was drilled to a depth approximating 3,200 feet near the village Vinton. No details concerning this have been received, but the Clinton sand was not found, and, of course, neither oil nor gas was secured.

JACKSON COUNTY.

Four wells to the Clinton sand have been drilled on Section 20 of Washington Township, two on land of the Buckeye Coal Company and two on the farm of Richard Wills. No. 2 on the Buckeye Coal Company tract was a gas well having rock pressure of 980 pounds and an open flow of 4,000,000 cubic feet per day. No. 1 on the Wills farm started at 500,000 cubic feet. The remaining two wells were dry. Following is a record of Buckeye No. 2:

		Thickness. Feet.	To bottom of formation. Feet.
Conductor		16	16
Casing 10 inch, 74 feet			
Berea sand		20	660
Casing 8¼ inch. 680 feet.			
Bedford and Ohio shales		794	1,454
"Big lime"		596	2,050
Shales from 1,750 to 1,760 feet.			
Casing $5\frac{3}{16}$ inch, 1,946 feet.			
Shales: chocolate	140 feet	205	2,255
white	40 feet		
brown	15 feet		
white	10 feet		
Clinton sand		8	2,263
Shales: white	44 feet	52	2,315
red	8 feet		
Bottom of well at 2,315 feet.			

No. 1 on the Wills farm showed only four feet of sand, and No. 2 none at all. These figures can hardly be rated encouraging to the prospector. As previously reported, the "Big lime" continued to contract, while the underlying shales thicken.

About the year 1903-4 a test was made on the Gerkins farm, about three miles northwest of Oak Hill, and a depth of about 2,700 feet reached, but no Clinton sand was found.

PIKE COUNTY.

A few tests have been made for oil or gas in the Clinton sand in this county. Thus far neither has been found, and there is no reason to expect better results. One of the tests was at Waverly, and because of its depth and the unusually complete record a full report of it is given. First acknowledgment is made to Mr. Peru Hutt, who not only kept a detailed log of the well, but also 68 samples of the drillings, representing every type of rock penetrated. He generously permitted the writer to examine these, and furnished also an interesting account of the trials and tribulations of drilling a well more than 3,000 feet deep. The latter will be reviewed, and then the well record given.

In the spring of 1908 a group of men from the East started drilling, the location being in a hollow a little north of west of the Detroit, Toledo & Ironton Railroad station at Waverly. All went well until at a depth approximating 780 feet, when a heavy flow of water was encountered. Casing was inserted, and drilling resumed, when another flow was found. A longer string of casing replaced the first one, and again the drilling started. Soon another heavy flow was found, and the casing had to be withdrawn two or three times more before the lower limit of water was passed. So abundant was the supply that it flowed from the top of the well, and when it was cased off, flowed outside to the surface, and now from the abandoned hole. It has a strong odor of hydrogen sulphide. The water came from the "Big lime," as anyone who has read the preceding pages might conclude.

These troubles delayed the drill, and progress was slow. When a depth of 1,428 feet was reached the company was without the necessary funds to continue, and citizens of the town, desiring to see a first-rate test made, organized the Waverly Oil & Gas Company. When drilling was again resumed, January 4, 1909, it was found that the hole had filled to a depth of about 400 feet with shales or clay, the result of a cave from below the "Big lime." The hole was soon cleaned, and good progress made to a depth of 1,960 feet, when the Trenton limestone was struck, which checked, but did not stop, the advance. At 2,250 the rock became harder, and this variety continued until the bottom of the formation was reached, at a depth of 2,810 feet. A trace of oil was found at a depth of 1,960 feet. While this great formation was being penetrated, the caving of the overlying shales became so troublesome that the casing had to be drawn again and a string inserted that reached below the base of the cave. By that time the hole had filled more than 1,000 feet

with the shales or clay, and after removing 700 feet the cable broke and the drill buried itself in the shales remaining in the hole. Fishing tools were gotten, and after working four days the drill was recovered.

A new cable was ordered at once and received on the following day. Drilling was resumed three days later, the tools advancing about one foot an hour. On March 13 the bailer broke, leaving that necessary tool at the bottom, about 2,725 feet below the surface. This was fished out without great trouble and the base of the Trenton limestone reached. On entering the sandstone that underlies that formation, water was again encountered; at first this was not abundant, but as the drill descended the volume increased, and at a depth of about 2,900 feet rose to within 400 feet of the surface. At about 2,960 feet the bailer was again lost and for nine days rested on the bottom of the well.

Water in the hole made drilling extremely slow with a hemp cable, and a wire one 3,500 feet in length and seven-eights of an inch in diameter was purchased. April 20, 1909, at a depth of 3,188 feet the new cable broke and the tools with about 3,000 feet of the wire were in the well. These were recovered the next day, but ere long the cable broke again. Not to allow one part of the outfit to monopolize attention, the walking beam gave way on June 7, but was replaced with a timber from the forest primeval, and work resumed a week later. The cable stranded the next day, but was spliced and drilling resumed without notable interruption until June 30 when the bailer with 400 feet of the sand line were lost in the well. Again it was fished out and the drill started.

June 18 a new 3,500 foot wire cable was purchased and put to work on the 25th. Five days later the bit was lost in the well at a depth of 3,250 feet and the bailer on top of it. While fishing for the tools on July 11, the new cable severed, leaving the fishing tools and 1,700 feet of cable in the hole. The board of directors met July 14, 1909, received a report from their manager and suspended operations. Later the casing was drawn and all that now remains to show for the $12,000 is an artesian well with a pungent odor and a derrick that will soon yield to a stiff wind. The troubles recorded were not the only ones, numerous as they were, but sufficient to show the difficulties that may accompany drilling very deep wells.

Record.—Waverly Oil & Gas Company's well at Waverly, Ohio. Began drilling in the spring of 1908; suspended operations July 14, 1909. Elevation of well head 575 feet above ocean level.

This record with samples of drillings was kept by Mr. Peru Hutt. The figures are his, but the formation names were supplied by the writer after an examination of the samples. Mr. Hutt's interpretation of the record is different from that which follows:

Number of sample.		Thickness. Feet.	To bottom of formation. Feet.
1	Mantle rock	35	35
2	Black shale	300	335
3	Gray shale	150	485
4–5	Fawn colored limestone	140	625
	Sulphur water at 510 feet.		
6	Gray sandstone	50	675
7	Gray limestone	25	700
8	Buff limestone	50	750
9	Dark gray limestone	25	775
	Salt water and gas at 780 feet.		
10	Dark gray limestone	15	790
11	Yellow limestone with shale	45	835
12	Black, yellow and white limestone	60	895
13	Brown mottled limestone	80	975
14	Chocolate shales	40	1,015
15	Green shales	50	1,065
16	Light brown and green shales	303	1,368
17	Gray shales	532	1,900
18	Dark and light shale with trace of oil	10	1,910
19	Dark shale	50	1,960
20–22	Dark and gray limestone	170	2,130
23	Gray limestone	60	2,190
24	Buff limestone	210	2,400
25	Dark limestone	20	2,420
26–27	Buff limestone	20	2,440
28	Darker buff limestone	45	2,485
29–32	Light and dark limestone	255	2,740
33	Light limestone and dark shales	8	2,748
34	White sandstone		
35	White sandstone and dark green shales		
36	Dark green shales and white sandstone	82	2,830
37	Gray sand		
38	Light yellow sand		
39	Gray sand (show of oil and gas from 34–39)		
40	Gray sand and dark shale	75	2,905
41–43	Dark shales, fossiliferous	50	2,955
44–47	Buff limestone and dark shales	65	3,020
48	Dark green shales, soft	10	3,030
49–68	Buff limestone and dark shales	285	3,315
	Gas at 3,270 and 3,322.		

In measuring an error of about 3 per cent was made. The depth of the well was 3,220 feet.

Simplifying this record we have the following:

		Thickness. Feet.	To bottom of formation. Feet.
1	Mantle rock	35	35
2–3	Ohio shales	450	485
4–13	"Big lime"	490	975
14–19	Silurian and Ordovician shales	985	1,960
20–33	Trenton limestone	808	2,768
34–40	St. Peter's sandstone and shales	157	2,925
41–43	Dark shales, fossiliferous, unclassified	50	2,975
44–68	Buff limestone and dark shales (Lower Magnesian?)	360	3,335

At a depth of 140 feet in the "Big lime," a bed of white sandstone, reported 50 feet thick, was found. This fact, with the drillings above and below responding but slightly to cold acid, misled those interested in the well and the entire series was called sandstone or sandstone and shales. When these drillings, with the exception of the sand, were treated with hot acid, free effervescence took place, showing that the rocks are dolomitic limestone. The lower 80 feet resemble the Clinton limestone along its outcrop and are so classified; in fact the 60 feet above this may also be placed with the Clinton, but the evidence was not conclusive. The writer was unable to determine how much of the remaining parts belonged each to the Niagara, Monroe and Devonian limestones. Probably the sandstone forms part of the Monroe ("Lower Helderberg").

The shales between the "Big lime" and the Trenton represent the Clinton, Medina (if that formation is present in southern Ohio) and the Cincinnati and Utica of the older Ohio reports. As the section shows, the Clinton sandstone was not found, substantiating the statement already made that it does not extend as far west as the Scioto River.

The Trenton limestone is represented by 808 feet, a somewhat greater thickness than has heretofore been reported for southern Ohio. It contains little shale, has a buff, gray or dark color and responds freely to cold acid, showing it is not dolomitic. In the latter respect it differs from the great repository of oil in northwestern Ohio.[1] The upper 300 feet contained some shale and drilled fairly easily, but below that was solid limestone, except eight feet at the base.

Below the Trenton is a formation whose name is not well known in Ohio geology. In this record it consists of 82 feet of light colored sand and a subordinate quantity of shale, overlying 75 feet of gray sand with a larger proportion of shales. A similar formation underlies the Trenton in Illinois and other western states, and has been named the St. Peter's sandstone. This name is applied to the rocks in question in Ohio.

The St. Peter's sandstone is underlaid with 50 feet of dark shales that stuck to the bit and hence were hard to drill. Specimens brought up by the bailer show numerous fossils, but the fragments are so small

[1]Orton, Edward. *Geol. Surv. of Ohio*, Vol. VI, p. 103.

that the forms are hard to identify. Whether these shales should be classed with the overlying formation or the one beneath, the writer is unable to say.

The lowest rocks penetrated in this well, representing 360 feet, consist of buff limestone interbedded with dark shales, the latter resembling the 50 feet reviewed in the last paragraph. The proportion of shale to limestone varies. In No. 58 the two appear to be nearly equal; in 59 the shale is less abundant; in 67 it comprises more than 50 per cent.; in 68 the drillings resemble pepper and salt; in other bottles the limestone is most abundant, and in some there is just enough shale to be easily visible. The limestone responds slowly when treated with cold acid, but acts freely when the acid is hot, indicating its magnesian or dolomitic character.

Below the St. Peter's sandstone in Illinois and neighboring states lies the Lower Magnesian limestone. The rocks in the basal portion of the well at Waverly resemble those in composition and position, and are probably their eastern extension.

LAWRENCE COUNTY.

This, the southernmost county in the state, has been tested to or below the horizon of the Clinton sand at two or more places.

In 1885 a well was begun at Ironton for natural gas. Not finding the fuel in the Berea sand, which was struck at 1,010, it was decided to push on to the Trenton, which was then attracting so much attention in Northwestern Ohio. Work was continued somewhat irregularly until the middle of 1887, when a depth of 3,600 feet was reached. Dr. Orton was of the opinion that the Trenton was probably struck at 3,440 feet. No Clinton sand was reported, and it is a fair conclusion none was found. Following is Dr. Orton's interpretation of the record:

	Thickness Feet.	To bottom of formation Feet.
Coal measures	282	282
Logan and Cuyahoga groups	728	1,010
Berea sand	47	1,057
Bedford and Ohio shales	770	1,827
"Big Lime"	584	2,411
Silurian and Ordovician shales	1,029	3,440

Trenton limestone at 3,440 feet.
Bottom of well at 3,600 feet.

It should be stated that Dr. Orton was not sure that the Trenton was reached at 3,440 feet, but at any rate that figure is not far from the true position. The well head he places at a "little less than 500 feet above tide."

[1]Orton, Edward. *Geol. Surv. of Ohio,* Vol. VI, p. 304.

Not believing the result of this test condemnatory for the county, another well was drilled in 1906, the location being at Mt. Vernon, near the middle of Decatur Township. Following is the record:

	Thickness Feet.	To bottom of formation Feet.
Berea sand	25	1,120
Bedford and Ohio shales	690	1,810
"Big lime"	620	2,430
Shales of various colors	289	2,719
Red rock (shales)	11	2,730

This well, too, found no Clinton sand. Probably the red rock struck at 2,719 feet lies just below the desired formation. These tests are all the more discouraging because in neither was the Clinton sand present, leaving the prospect anything but flattering for the county.

CHAPTER III.

THE SEARCH FOR THE CLINTON SAND NORTH OF THE BREMEN FIELD.

The extension of the gas field into Knox County greatly encouraged drilling in Northern Ohio, with the result that tests have been made to the shore of Lake Erie. These have shown the Clinton sand somewhat spotted in Richland County, usually if not always absent in Huron, thin and uncertain in Lorain and Cuyahoga. Apparently the sand thickens to the east and southeast, but the tests have been few, owing to the depth of the formation. While both oil and gas have occasionally been found, the yield has not been in proportion to the great expense.

LICKING COUNTY.

While this county has long been a heavy producer of natural gas from the Clinton sand, it has not yielded oil in commercial quantities, with the exception of an occasional well in the gas belt.

In September, 1910, a well was completed on the Deeds farm, about two miles west of Union Station in Union Township, and 10 feet of sand found, the top at 2,218 feet. After shooting, the hole filled 1,800 feet with oil, and when tubed began flowing at the rate of 30 barrels per day. About a half-mile northeast is a gas well, and another the same interval due west. Two dry holes have been found, one three-quarters of a mile southwest and the other a mile southeast of the oil well.

In October, 1910, a well was completed on the Ashcroft farm, in the southeast corner of Fallsbury Township. The Clinton sand was struck at 2,875 feet, and was 40 feet thick. It began producing oil but the rate has not been determined at date of writing. For the following record of this well the survey is indebted to Mr. G. C. Scott, of Columbus:

	Thickness Feet.	To bottom of formation Feet.
Drive pipe	58	58
Berea sand	20	632
Casing 6⅝ inch, 650 feet.		
Bedford and Ohio shales	1,168	1,800
"Big lime"	912	2,712
First water at 2,400 feet.		
Second water at 2,440 feet.		
"Big water" at 2,475 feet.		
Casing 5 3/16 inch, 2,612 feet.		
Shales	163	2,851
Clinton sand	40	2,915

Break in sand from 2,892 to 2,894 feet.
Depth of well 2,927 feet.

KNOX COUNTY.

While this is a large producer of gas from the Clinton, its yield of oil from that formation is small. At the present time (August, 1910) the producing wells number about a baker's dozen and are scattered over four townships in the eastern and northern parts of the county. The results have not been at all in harmony with the labor, and in fact the fuel secured has been simply enough to lead the operator on with the hope that a large deposit might be near.

Jackson Township—This contains the best known pool of oil in the county, but it is of doubtful value. In August, 1904, a well was completed on the McKee farm in Section 14. The Clinton sand was struck at 2,771 feet, and began flowing oil at about 35 barrels per day. A second well was sunk at once, and a very small producer secured. The third well was drilled a few hundred yards farther west, on the Hall farm, and a 10-barrel producer secured. The fourth well of the field was drilled on the same section, but a little bit farther south, on land of John Wolf, the result being similar to that on the Hall farm. One more producing well was secured in this field. It was located between the Wolf and McKee wells, and started at about 15 barrels per day. An effort to extend the pool northward met with failure. A dry hole was drilled to the north and just across the road from the McKee well, and a like result followed on the Blymer farm about two miles to the northwest. Here, however, a little oil and gas were secured. The latter was used a short time for a boiler, and then the well was abandoned. The last failure recorded was on the Kerr farm, in the southeastern quarter of Section 4.

Four of the five producing wells secured in this township are still producing. The McKee, which all along has been the best in the field, now pumps about 8 barrels in 10 hours, while the other wells are smaller and not pumped daily. Each makes about one and one-half barrels of water per day, indicating that this is in the sand, for it is hardly possible that the casing in all would leak at the same rate.

Oil from the McKee well has a dark color, and at a temperature of 68° F. a density of 35° Beaume.[1] The oil is shipped by pipe line to Cooperdale, on the C. A. & C. R. R.[2]

Finally there is added a record of the McKee well, furnished by the driller, Mr. Irving Forbing, of Mt. Vernon:

		Thickness Feet.	To bottom of formation Feet.
Drive pipe, 8 inch		30	30
Berea sand		10	680
Casing 6½ inch, 680 feet.			
"Big lime"		863	2,623
Clinton	sand 35 feet; shale 4 feet; sand 10 feet	49	2,820

[1]For analysis of this oil see p. 17.

[2]This pool is commonly known as the Bladensburg.

The division of the oil rock into two parts by a few feet of shales, while uncommon, is occasionally reported from different parts of the State.

Butler Township.—Only one test to the Clinton sand is reported from this township. This was on the Beal farm in Section 4 and was a failure.

Union Township.—Two wells are reported to the Clinton. About the year 1907 a test was made on land of David Colopy in Section 22; it gave a little gas, but not enough for commercial purposes and was abandoned. The other well is just west of Danville and yields gas.

Jefferson Township.—This lies north of Union and comprises the northeastern corner of the county. Nine wells to the Clinton sand have been drilled, the result being four small oil wells and five failures. On land of Henry Black in the extreme southeastern corner of the township, two small oil wells have been secured. The first, which was drilled about 1907, began flowing 5 barrels of oil per day, but a little later an accident occurred and the well was ruined. About 1908 the second well was completed and is reported to have begun producing approximately 17 barrels of oil daily. It is now pumped every other day.

About one mile west of the hamlet, Greer, three wells have been sunk to the Clinton, the result being two oil wells and one dry hole. The well on the Tisserand farm was drilled about 1904 and is still producing. The other successful well is reported to have begun flowing 25 barrels per day and still yields some oil. South of these wells and near the middle of Section 8 a test has been made, but the result was failure. Two wells are reported from the southern half of Section 14; one yielded some gas, but the other was a complete failure.

Howard Township.—This lies north of the eastern terminus of the great gas field and has been tested to the Clinton in at least 4 places. The only well that made a show of success was drilled about one mile south of Howard on the Lindza Horn farm, perhaps in 1908. It started producing 10 barrels of oil per day and now yields about half that quantity. About two miles west of this place the result was failure and the same is true of two wells near the village, Howard.

Brown Township.—This lies north of Howard and has been twice tested, both being in the southeastern corner of the township. About 5 years ago a well was drilled on land of Channing Rice in the valley of Jellow Creek, but was dry. In 1909 a test was made on the farm of Edward Grant, approximately a mile southwest of the Rice well, and like the latter was a failure.

Monroe Township.—This lies northeast of Mt. Vernon and has been tested to the Clinton in at least three places. One of these was near the middle of the eastern border of the township and two along the western. All were dry.

Pike Township.—Only three Clinton wells are reported from this township. About 1906 a gas well was secured on land of Robert Shira in

the southwestern quarter of the township. The rock pressure was reported at 1,250 pounds per square inch. In 1909 a test was made about a mile and one-half to the northwest on land of James Phillips, and a small oil well secured. It started at 5 barrels per day and is still producing. A well drilled on the farm of Thomas Simmons in the south central part of the township was a failure.

Berlin Township.—Three small oil wells were secured in 1906 and 1909 in the Clinton on land of Joseph Love, near the eastern border of the township. These started at from 5 to 15 barrels per day and are still producing. A half mile to the northwest another test was made with the hope of extending the pool, but without success. Failure also resulted from two wells, one drilled about a mile northeast of Fredericktown and the other about twice that distance southeast of the village.

Other Townships in Knox County.—The part lying south and west of the county seat comprises an important part of the great gas field, but that constitutes no part of this bulletin and so will not be discussed. The territory near or along the western border of the county has been amply tested, but without favorable results.

RICHLAND COUNTY.

One small pool of oil has been found in the Clinton in the southeastern corner of the county. While the production from this has been small and the balance is probably on the wrong side of the sheet, the scientific problems presented are of more than ordinary interest. Considerable drilling has been done farther north, but the results have been unfavorable.

Worthington Township.—This is the extreme southeastern corner of the county and contains the one pool of oil already referred to. For the history of this, the Survey is indebted to Judge F. O. Levering, of Mt. Vernon.

In June, 1905, a well was completed by the Butler Oil & Gas Co., on land of Mary McClellen in the southwest quarter of Section 28. The Clinton sand, 6 feet thick, was struck at a depth of 2,518 feet and gave a heavy flow of gas. The rock pressure reached the astonishing figure of 1,260 pounds to the square inch and the open flow started at 4,700,000 cubic feet per day. August 1, 1910, it was yielding 150,000 cubic feet against a line pressure of 200 pounds to the square inch.

The next test was in the northwest quarter of Section 33, but no Clinton sand was found and of course the well was a failure. The third well in the field was on the Mengert heirs farm in the northwest quarter of Section 33. It was completed in December, 1905, and its record is unique among the many thousand wells of Ohio. No tankage had been provided and so the flow during the first day was not determined, but it was estimated at 200 barrels and the *oil was water white*. The first day the oil could be measured, the flow was 132 barrels. By the close of January,

1906, the production had dropped to 87 barrels per day, and about November 1, 1906, the yield had become so small that it was abandoned as an oil well and used for gas, of which it had been prolific from the start.

The production all told was about 1,600 barrels of oil, and was all of the water white variety. It commanded a price 10 cents in advance of the regular Pennsylvania grade. People residing nearby used the oil in lamps and lanterns, for which it seemed well adapted, but the owners, fearing explosions, stopped this practice. No accident resulted from its use. The well is still used for gas and its owners state that it will produce small quantities of the white oil now if allowed to flow a few days.

Following are a few facts from the driller's record:

	Thickness. Feet.	To bottom of formation. Feet.
"Big lime"	890	2,430
Clinton sand	6⅓	2,516⅓

This shows that the interval between the "Big lime" and the oil and gas rock is only 80 feet, which is much less than usual in other fields. The "Big lime" is normal and the short interval below it may give the Clinton sand a low dome shape. The sand had a gray color and was quite soft. No water at all was produced while the well was flowing oil, and very little after it began to be used for gas. It was shot with 20 quarts of nitroglycerine.

Greatly encouraged by this well the company began three additional ones in the spring of 1906. In the meantime the Standard Oil Company had entered the field and started three strings of tools at work. For a 40-acre lease this company is reported to have paid $7,700 on which it drilled one well that was a total failure; and $3,500 for a 67-acre lease, on which it secured two oil wells, one starting at about 5 barrels and the other at approximately 15. Toward the close of 1907 these were abandoned as oil wells, but one was used for gas about a year longer.

Of the three wells started by the Butler Oil & Gas Company, referred to in the beginning of the preceding paragraph, two were dry, while the third (drilled between two dry holes), completed in March, 1906, started flowing 40 barrels of water white oil. In the following September the well was shot with 30 quarts for the first time, the production of both oil and gas being notably increased. Later the flow of oil having again become small, the well was connected with gas mains and is still used in that way. In April, 1906, the company went into the hands of a receiver and sold out the following June to Waight & Levering, who are the present holders of the property. Later these men drilled a dry hole in the southwest quarter of Section 28, one on the northeast quarter of Section 32 and another on the north-

west quarter of the same section. The last well drilled in the field was located on the southeast quarter of Section 29. This is about a half mile from the nearest gas well, but the rock pressure was only 600 pounds while the open flow started at 5,000,000 cubic feet per 24 hours.

When the excitement was at its highest in the spring of 1906, Smith, Kerr & Neely entered the field and secured a small oil well. This flowed at first, but later was pumped, and was abandoned in about two years. Still believing in the territory, the Fredericktown Oil & Gas Company drilled three holes in the northwest quarter of Section 28, securing two gas wells, one of which was very small and a dry hole. Seventeen wells in all were drilled in the Butler field. Eight of these were total failures, involving an expense aside from leases of at least $30,000.

All oil wells in this field produced the water white variety that resembles kerosene. As has already been shown, these were short lived, produced much gas and always or nearly so changed to gas wells. The rock pressure in the field was not uniform, but ranged from approximately 600 to 1,260 pounds. Not a well was producing oil in 1910.

Finally there is given a record for a well, the first drilled in the field:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	56	56
6⅝ inch casing, 555 feet.		
Berea sand at 600 feet.		
"Big lime"	881	2,391
Clinton sand	6	2,524
Total depth 2,559 feet.		

The sand is thin, and, according to Judge Levering, was absent wherever oil or gas was wanting. Formations to the base of the "Big lime" were regular, but those below were not so. Wherever oil was found the interval between the sand and the limestones was reported less, due to a rise in the oil rock. According to this the Clinton is uneven, forming very low domes and shallow basins. In the higher of these, oil was found and in the lower gas.

Outside of Worthington Township, quite a number of Clinton wells have been drilled in Richland County, but the results have been far from satisfactory. In Jefferson Township, along the southern edge of the county, at least half a dozen tests have been made, but the only reward has been a small gas well or two. Four wells have been sunk in the southwestern corner of Monroe Township, three of which were failures, while the fourth yielded gas.

Madison Township contains the flourishing manufacturing city of Mansfield, and, as might be expected, the rocks have been tested for

mineral fuels. As early as 1886, a well in search of gas was drilled, reaching a depth of 2,005 feet, but was a failure.[1] Twenty years later a test was made on land of A. Burnison, about two miles southwest of Mansfield. The well record, provided by Joseph Schrier, is as follows:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	125	125
Berea sandstone	40	600
"Big lime"	915	2,215
Flood of salt water at 1,990 feet.		
Shales	54	2,269
Medina shales (red rock) at 2,270 feet.		
Bottom of well (in red rock) 2,435 feet.		

As the record discloses, the much sought after Clinton sand is wanting and it is doubtful if it exists as a continuous or well-marked formation farther west than Mansfield. Patches of it, however, may from time to time be expected. The sand is very uncertain also in the southern half of the county and according to Judge Levering, of Mt. Vernon, the absence of oil or gas is characterized by the absence of the sand also.

This well was not without reward. At a depth of 1,910 feet or 610 feet in the "Big lime" a heavy flow of gas was struck. The closed or rock pressure is reported as having been 580 pounds and the open flow 1,200,000 cubic feet per day. From that time the drill has been at work irregularly in the neighborhood, and in all about 16 wells have been drilled to the "lime," only two or three of which were failures. The wells varied considerably in production, the largest having started at 3,500,000 cubic feet per day. The producing rock is said to be a limestone and not a sandstone in the "lime." Its position is usually about 640 feet in that formation, but figures of 390 and 500 are reported. The gas has a pungent odor and is not suitable for domestic purposes, but does very well for boilers. In drilling, care must be exercised not to strike the "big water" lying below the gas rock.

Along the P., Ft. W. & C. R. R., about two miles southeast of Mansfield, a Clinton well has been drilled, but no information concerning it has been secured beyond the fact that it was dry. A well is now drilling about three miles east and a little north of the one just mentioned. In Weller Township, northeast of Mansfield, two tests have been made: one at or near the hamlet, Pavonia, was without reward, and the same is true of the other, about a mile north and a little east of Epworth. In the last well the Berea was reported at 600 feet, the "Big lime" at 1,500, and the Clinton at 2,475. Doubtless more money and energy

[1]Orton, Edward. *Geol. Surv. of Ohio*, Vol. VI, p. 365.

will be expended in seeking oil or gas in the Clinton in Richland County, but judging from information now available the results are not promising.

COSHOCTON COUNTY.

Records are at hand of only two wells to the Clinton sand in this county. One was drilled on the farm of William Bumpus, in Tiverton Township, near the Knox County line, in 1904. The salient features of the record are as follows:

	Thickness. Feet.	To bottom of formation. Feet.
Berea sand, base of		700
Bedford and Ohio shales	1,100	1,800
"Big lime"	950	2,750
Showing of oil at 2,330 feet.		
Break in "Big lime" at 2,650 feet.		
Clinton sand	35	2,907
Bottom of well at 2,943 feet.		

This well was shot, but made nothing better than a showing of oil.

A year later a well was drilled on the George Oxley farm near the western margin of Perry Township, and the record is similar to the one just given. The Clinton sand was reached at 2,960 feet and was 52 feet thick, but contained 4 feet of shales in the lower part. It made nothing better than a show of gas. These two wells show unusual thicknesses of sand and lead to the hope that the stratum may be both continuous and in good quantity. Prospective drillers, however, should note the increasing thickness of the "Big lime."

HOLMES COUNTY.

This county lies north of Coshocton and like that has been but little explored so far as the Clintom sand is concerned. As will be surmised, the one obstacle is the great depth. A test made on the Colopy farm in the southwestern corner of Richland Township found the Clinton sand at 3,059 feet with the following structure:

	Feet.
Sand	14
Shales	24
Sand	22

The rock was shot, but yielded nothing more than a show of oil.

On March 1, 1904, a well was begun on the farm of Peter Schlarb about three miles west of Millersburg. Troubles of various kinds, especially those resulting from heavy flows of brine, impeded the work so that the well was not completed until August 1. The record as provided by Mr. B. S. Stretton follows:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	86	86
Sand and shales	178	264
Casing 6⅝ inch, 264 feet.		
Shales	431	695
Berea sand	45	740
Bedford and Ohio shales	1,180	1,920
"Big lime"	1,152	3,072
Shales	21	3,093
Limestone	6	3,099
Shales	22	3,121
Clinton sand	67	3,188
Total depth 3,211 feet.		

The first salt water in the "Big lime" was found at 2,150 feet, and a much larger one at 2,806. This was cased off, but at 2,900 feet another flow was encountered and the casing was reset. The first screw in the Clinton sand the hole filled with water and the well was finished with that handicap. This report of water in the sand is most unusual and leads to the suspicion that it came from the "Big lime." The well was a total failure so far as oil and gas are concerned.

A test has also been made on the Kaylor farm along the western edge of Knox Township, the only reward being a show of gas. An unusually good record of this well was kept and is given below:

	Thickness. Feet.	To bottom of formation. Feet.
Sand and gravel	77	77
Shales and sandstone	238	315
Limestone	20	335
Shales	280	615
Berea sand	10	625
Show of oil in Berea.		
Bedford shales (red)	90	715
Ohio shales	1,010	1,725
"Big lime" { limestone 470 feet; shales 7 feet; limestone 443 feet; brown limestone 40 feet }	960	2,685
Shales	15	2,700
Limestone	35	2,735
Shales and shells	48	2,783
Black peppery limestone	9	2,792
Limestone with various colors	10	2,802
Limestone, white and soft	18	2,820
Shales and shells	31	2,851
Clinton { sand 5 feet; shales and sand 9 feet; sand and shales 14 feet }	28	2,878
Shales and shells	6	2,884
Shales	24½	2,908½
Shales (red)	6½	2,915
Shales and shells	42	2,957
Bottom of well at 2,957 feet.		

WAYNE COUNTY.

Only four wells have reached the Clinton sand in Wayne county. One of these was a total failure while the remaining three produced gas. The result, however, has fallen far short of making the search profitable. In 1909 a well was drilled on the Ryland farm in Section 6 of Plain Township, the log of which follows:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	40	40
Casing 8 inch, 450 feet.		
Casing 6½ inch, 2,000 feet.		
"Big lime"	1,060	2,760
Clinton sand	15	2,920
Bottom of well at 2,964 feet.		

The result was a flow of gas that was estimated at from 1,000,000 to 2,000,000 cubic feet per day and a closed or rock pressure that measured 650 pounds to the square inch. In the same year a well was drilled on a farm that joins the Ryland on the northeast. The Clinton sand was found, but was thin and without fuel of any kind. Both wells showed oil in the Berea. Early in the spring of 1910 a well was completed to the Clinton sand on the southwest quarter of Section 17 of Congress Township. The top 8 feet of the sand was of good quality, but farther down it was mixed with shales. The well is classed with the small gas producers.

The fourth test in the county was about one mile west of Wooster and was completed July 1, 1910. The well head is approximately 860 feet above sea level. For the following record and facts, the Survey is indebted to Mr. H. B. Odenkirk, of Wooster:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe 10 inch	57	57
Berea sand	30	495
Casing 8 inch, 509 feet.		
Bedford shales (red)	50	545
Ohio shales	1,285	1,830
Heavy flow of brine at 2,055.		
"Big lime"	1,085	2,915
Salt 2,360 to 2,400 feet.		
Casing 6⅝ inch, 2,126 feet.		
Shales	189	3,104
Clinton sand	31	3,135
Bottom of well at 3,140 feet.		

After shooting the sand with 80 quarts of nitroglycerine, it began flowing gas at the rate of 1,440,000 cubic feet per day, but a week later, during which it was blowing freely into the air, it measured 325,000 cubic

feet. The rock pressure was 850 pounds. It showed some oil also, but this had not been pumped when the well was visited in August, 1910. Thinking that another shot would improve the well, an effort was made to draw the tubing, but without success. The gas was used for a short time in burning bricks, and that may be its permanent service. No water was found in the sand, which lies 2,244 feet below ocean level. Interesting to note, the well disclosed 40 feet of rock salt, this being reported free from shales or other impurities. It is the farthest south that this formation has been found.

ASHLAND COUNTY.

This lies west of Wayne and has been tested to the Clinton sand at more than a dozen places. These will now be reviewed:

Vermilion Township.—This is the only township in the county that has yielded fuel in commercial quantities and that is natural gas. In January, 1910, a well was completed on the farm of George W. Long near the southern margin of Section 9. and a gas well with a closed pressure of 1,000 pounds and an open flow of 230,000 cubic feet per 24 hours secured. The well head is 1,250 feet above tide level, and the log is as follows:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	145	145
Berea sand	18	750
Bedford and Ohio shales	920	1,670
"Big lime"	980	2,650
Water at 1,900 feet.		
Casing 6⅝ inch, 2,015 feet.		
Clinton sand	3	2,792
Bottom of well at 2,852 feet		

Three additional wells have been drilled in the township and gas producers secured. One of these was very large and with a rock pressure of 1,075 pounds, but the yield of the remaining two was much smaller. Several locations have been made near these and the Clinton will have been reached ere these lines are in print. The thickness of the sand ranges from 3 to 20 feet.

Hanover Township.—About 1905 a well was drilled on the Stull farm near the southern margin of the township. The Clinton sand, two feet thick, was found at 2,763 feet, but was without oil or gas.

Green Township.—A well to the Clinton sand is reported about one mile north of Perrysville, but no information has been secured concerning it beyond the fact that it was dry.

Mohican Township.—A Clinton well is reported a short distance northwest of Jeromeville, but it disclosed neither oil or gas.

Jackson Township.—March 9, 1906, a well was completed on the Utz farm, northwest quarter of Section 21, the altitude of the well head being 1,265 feet. The following record of this well was secured:

	Thickness. Feet.	To bottom of formation. Feet.
Berea sand	15	670
Bedford and Ohio shales	995	1,665
"Big lime"	1,100	2,765
Shales	96	2,861
Clinton sand	12	2,873

The sand lies 1,611 below sea level while in the Long well it was only 1,539, a drop of 72 feet in 12 miles or 6 feet to the mile, the direction being nearly northeast.

The Utz well showed oil, was shot and the pump attached. The yield, however, was small and the well was soon abandoned. Encouraged by this, another hole was drilled in 1909 just across the road, a good flow of gas being secured, but this soon gave out. Two additional wells have been drilled in this township; one in the northeastern corner on the Landis farm in Section 3, and one in the southwestern corner on the Kelley farm in Section 29. The first found 3 feet of sand, the second little or none, and both wells were failures.

Ruggles Township.—Three wells have been reported in this township, but the data are very indefinite and unsatisfactory. Possibly two may not have reached the Clinton. All were failures.

MEDINA COUNTY.

Quite a number of Clinton wells have been sunk in the southwestern corner of this county, the result being 4 gas wells, one oil well and 3 dry holes. From two to three miles south of west of Lodi is the most promising territory. Even there the sand is thin, ranging from 5 to 12 feet, and the wells rather small. The general rock succession is shown by the following record of E. S. Albert well No. 1, the head being 920 feet above sea level:

	Thickness. Feet.	To bottom of formation. Feet.
Berea sand	10	396
Bedford and Ohio shales	1,116	1,512
"Big lime"	1,127	2,639
Water at 1,722 feet.		
Clinton sand	14	2,763
Bottom of well at 2,777 feet.		

This well is northeast of those in Jackson and Vermilion Town-

ships of Ashland County, whose sea level position has already been stated. The sand in the Albert well record, just given, lies 1,829 feet below sea level, a drop from the Utz well (page 62) of 218 feet or 27 feet to the mile.

North of the Lodi field a number of tests have been made. One in Chatham Township found the sand dry, while farther north, in Litchfield, the result is somewhat mixed. Near the middle of the southern part a dry hole was secured; but about two miles farther north, on the Stranahan farm, an oil well, starting at about 10 barrels per day, was the reward. In this the Clinton sand lies about 1,739 feet below sea level. Encouraged by this result, another test is being made about a mile to the west. Near the southern margin of Penfield Township a gas well has been secured and two additional tests are now being made, one north and one west of the producer.

LORAIN COUNTY.

This county, which borders on Lake Erie, has been tested at a number of places, and in Avon Township nearly 30 wells have been drilled, of which 15 were total failures. Following is a record of Kenzel No. 1, in the southeastern quarter of the township:

	Thickness. Feet.	To bottom of formation. Feet.
Drive pipe	63	63
Bedford and Ohio shales	957	1,020
"Big lime"	1,325	2,345
Casing 6⅝ inch, 1,425 feet.		
Salt from 1,535 to 1,570 and from 1,680 to 1,698.		
Clinton sand	8	2,420
Bottom of well at 2,480 feet.		

The Ohio shales lie immediately below the drift in this territory, and so the Berea does not appear in the well record. The "Big lime" contained much water, filling the hole 2,000 feet, but the Clinton sand, 1,722 feet below sea level, was free from water as well as oil and gas. Salt was found at two horizons in the "Big lime," and this useful mineral is reported in every well as far west as the meridian passing through Elyria. The Clinton sand usually ranges from 4 to 15 feet in thickness, but sometimes is wanting. The rock pressure for the field is about 1,000 pounds to the square inch, and the largest well is reported as having started flowing at the rate of 5,000,000 cubic feet per day. In general the wells are much smaller, and this fact, with the very large proportion of dry holes, has made the territory unprofitable.

Ridgeville Township lies south of Avon and has been tested at

three places, one each in the northeast and northwest corner, and one between these and a little farther south, but all were failures. In Sheffield Township, west of Avon, one test has been made, the location being near the Lorain & Elyria Electric R. R., and about a half mile from the southern line of the township. The head was about 650 feet above sea level, and the log is as follows:

	Thickness. Feet.	To bottom of formation. Feet.
Drift and shales	840	840
"Big lime"	1,230	2,070
Water at 1,075 feet.		
Clinton sand	7	2,204
Bottom of well at 2,405 feet.		

This well is reported as showing 80 feet of rock salt, but neither oil nor gas. The top of the sand lies 1,547 feet below ocean level, a rise of 64 feet from the Utz well, which is 32 miles nearly due south. In other words, the southward dip of the sand in this part of Ohio is less than 2 feet to the mile. Some years ago a well was drilled at Oberlin, but no record has been secured of it. Neither oil nor gas was found.

It may be worth while at this place to give a record showing the Trenton limestone, since many prospectors are not clear as to the position of the "Big lime" and Clinton with reference to the Trenton. The record which follows is that of the Citizens Well No. 1, drilled at Norwalk, in 1887:

	Thickness. Feet.	To bottom of formation. Feet.
Drift	85	85
Bedford and Ohio shales	355	440
"Big lime"	850	1,290
Niagara and Clinton shales and limestones	400	1,690
Medina shales	110	1,800
Ordovician (Lower Silurian) shales and limestones	845	2,645
Trenton limestone at 2,645 feet.		

This log does not show the Clinton sand for the simple reason that it does not extend that far west, its place being occupied by shales.

CUYAHOGA COUNTY.

Many tests for oil or gas have been made in this county. In 1886 a well was drilled at Newburg, in search of gas for a rolling mill, but at a depth of 3,000 feet the tools became fast in the well and it was abandoned. According to Orton, work was suspended in the Clinton

limestone which forms the basal part of the "Big lime."[1] A little gas was secured, and another well soon started, but with no better success. Since that time a number of tests on the western side of the county have reached the Clinton sand, but with little or no success. A well on the White farm just west of Rocky River showed a little oil, and that is occasionally dipped from the well by farmers and used as a lubricant.[2] Possibly the source of this was in the "Big lime" rather than in the Clinton sand.

In the summer of 1907, the East Ohio Gas Company drilled a well on the Gray farm about one mile north of Berea. The "Big lime" was struck at 1,075 feet and at 1,280 a flow of gas, reported at 500,000 cubic feet, was found. Work continued to 3,200 feet without finding the Clinton sand, and the well was abandoned.

About the same year (1907), three wells were drilled near Olmsted Falls, two of which were total failures, while the third yielded a little gas, though no use has been made of it. This well is on the Garfield and Caine farm and is about one-half mile west of the village. The record as furnished by the East Ohio Gas Company follows:

	Thickness. Feet.	To bottom of formation. Feet.
Drift	10	10
Drive pipe 10 inch, 19 feet.		
Berea sand	80	90
Casing 8¼ inch, 85 feet.		
Bedford and Ohio shales	1,120	1,210
"Big lime"	1,455	2,665
Casing 6⅝ inch, 1,540 feet.		
First salt water at 1,480 feet.		
Casing $5\frac{3}{16}$ inch, 2,613 feet.		
Heavy flow of water at 2,450 feet.		
Showing of oil at 2,300, 2,355 and 2,390 feet.		
Clinton sand at 2,680 feet.		
Total depth of well 2,770 feet.		

The well head is 780 feet above ocean level, and hence the top of the Clinton sand lies 1,900 feet below the same datum plane.

For the convenience of persons desiring to know the position of the Clinton sand in Northern Ohio, the following summary is given:

Ashland County.
- Vermilion Township.
  - Long well No. 1 .... 1,539 feet below tide level.
- Jackson Township.
  - Utz well No. 1 .... 1,611 feet below tide level.

[1]Orton, Edward. *Geol. Surv. of Ohio*, Vol. VI, p. 352.

[2]Manuscript of Professor Frank Carney.

Wayne County.
  Wooster........................2,244 feet below tide level.
Medina County.
  Harrisville Township.
    E. S. Albert well No. 1 ....1,829 feet below tide level.
Lorain County.
  Avon Township.
    Kenzel well No. 1..........1,722 feet below tide level.
  Ridgeville Township.
    Sheffield well No. 1 ....1,547 feet below tide level.
Cuyahoga County.
  Olmsted Township.
    Garfield and Caine well.....1,900 feet below tide level.

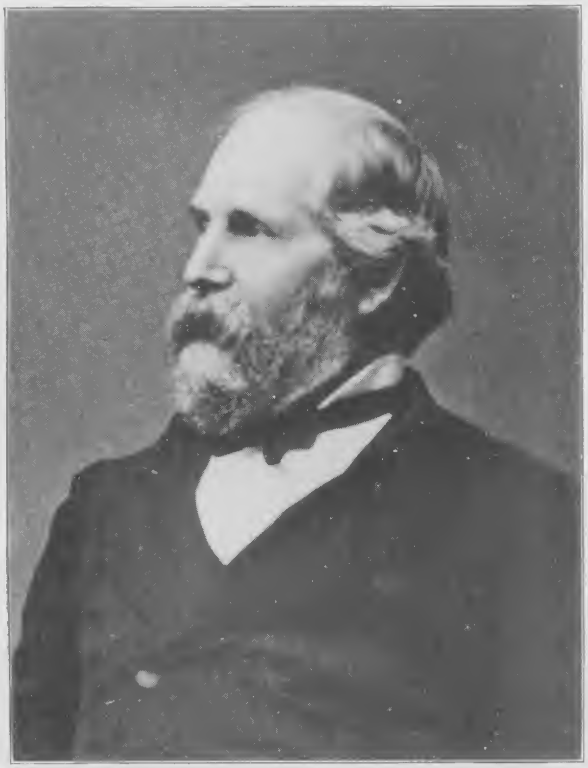
FOURTH SERIES, BULLETIN 13

THE MAXVILLE LIMESTONE

By WILLIAM CLIFFORD MORSE

November, 1910.

5—G. B. 13—1,000.



EBENEZER BALDWIN ANDREWS (1821-1880).

Professor of Natural Sciences at Marietta College from 1852 to 1869, and one of Ohio's leading geologists during the seventies.

DR. J. A. BOWNOCKER,

State Geologist.

Dear Sir:—I submit herewith my report on the Maxville limestone. It represents a somewhat careful and rather detailed study of this important formation which is represented at too many places in our state by only a gap—hiatus—in the stratigraphic record.

Very truly yours,

W. C. MORSE.

Ohio State University,
Columbus, Ohio, November 23, 1910.

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ACKNOWLEDGMENTS.

The study of the Maxville limestone was undertaken as a thesis requirement for an advanced degree at the Ohio State University (granted in 1908) under the direction of Prof. Charles S. Prosser, and has been continued until the present time. The writer wishes to express his appreciation of an inspiring teacher and his thanks for the many suggestions and criticisms. A grant of fifty dollars was made by the Ohio Academy of Science to defray a part of the expense of the field work. This amount furnished a beginning, and the author takes this opportunity of expressing his sense of obligation to that organization, through the former chairman of the executive committee, Prof. William R. Lazenby. Dr. John A. Bownocker, State Geologist, also kindly allowed the expense and salary for a number of days of field work performed during the summer of 1909. Mr. James Morse of Hocking County, and Mr. Samuel Rarick of Perry, very generously furnished a horse and buggy for a number of weeks without charge to the Academy or to the state. To both of these and to a number of other friends the writer is under obligation.

CHAPTER I.

INTRODUCTION AND BIBLIOGRAPHY.

LOCATION.

AREAS OF OUTCROP.

The Maxville limestone appears at the surface in an interrupted series of outcrops in the southern half of the state of Ohio. More specifically, the series extends from Kents Run and Jonathan Creek, near Zanesville, southwest to the Kentucky side of the Ohio River, near Wheelersburg. Because of the interruptions, the region is naturally divisible into three parts—a northern, a central and a southern area. The northern area extends from Kents Run to Logan, and within it the Maxville is most fully developed. It also contains the best exposures, since the Zanesville & Western Railway cuts through the formation in a number of places along Jonathan Creek. The southern area extends from Hamden to the Ohio River. Only a few exceedingly small and isolated patches of Maxville are found in this area. The central area lies between Logan and Hamden, and so far as known contains no exposures.

AREA BENEATH THE SURFACE.

Besides the few wells near the line of outcrop in which the Maxville was encountered, there are a large number of wells far to the east of this line in which the limestone is also found. These wells are located principally in Monroe and Washington counties, in the southeastern part of the state. So universally present is the limestone in this region that it has become an important horizon marker for the oil drillers.

EXPLORATION.

PREVIOUS FIELD WORK.

Practically all of the field work upon the Maxville limestone was done in the years 1869 and 1870. It was performed by Prof. E. B. Andrews, while engaged in the study of the rocks of the second district, which comprised nearly the whole of the twenty-three counties lying southeast of Columbus. Considering the large extent of the district and the limited time of study, the work was most accurately done, and Andrews will ever receive credit for discovering, naming and correctly determining the geologic position of the stratum.

PRESENT FIELD WORK.

The present study of the stratum was begun during the spring of 1906, and has been continued intermittently until the present time.

Days and weeks of consecutive work have been spent in the field. However, during most of this period only such time has been available for study as was not required for regular duties.

In the northern area all of the known exposures have been carefully studied and sections made of them. Within the central area the line of contact between the Waverly and Pennsylvanian has been crossed and recrossed time and time again in the hope of finding an exposure of the limestone, but in vain. The few known exposures within the southern area have been treated like those of the northern area.

In addition, the basal conglomerate—the Sharon— of the overlying Pennsylvanian series was studied in Licking and Summit counties. Blocks in the conglomerate were known to be fossiliferous, and were supposed to be of Maxville origin. In company with Professor Carney, these were studied and fossils collected in them in Licking County, and Professor Carney's own collection from the same locality was very kindly donated for study. A similar study was made in the Cuyahoga Gorge and at Boston Ledges in Summit County.

GEOLOGIC POSITION.

The Maxville limestone occurs at the top of the Mississippian series. It is underlain by the highest formation of the Waverly and overlain by the lowest formation of the Pennsylvanian series. Its position and relation to the other formations and members of the Carboniferous system is clearly shown in the following table:

Carboniferous system.	Pennsylvanian series.	Monongahela formation.	
		Conemaugh formation.	
		Allegheny formation.	
		Pottsville formation	Homewood sandstone. Mercer limestones and coals. Upper Massillon sandstone. Wellston coal (No. 2). Lower Massillon sandstone. Sharon coal (No. 1). Sharon conglomerate.
	Mississippian series.	Maxville limestone.	
		Waverly.	Logan formation.
			Black Hand formation.
			Cuyahoga formation.
			Sunbury shale.
			Berea formation.
			Bedford shale.

BIBLIOGRAPHY AND ABSTRACT OF LITERATURE

The literature relating to the Maxville stratum is taken up chronologically in the following pages. The references come first. These are followed by either short quotations or brief abstracts, and the latter in turn often by the present writer's interpretations.

Practically all of this literature pertaining to the Maxville is based upon Andrews's report of the field work which he performed during the years 1869 and 1870. That the subject of the Maxville limestone should reappear in state and other publications from time to time without further field work and reports is due primarily to two factors. These are (1) the questioning of the stratigraphical assignment of Andrews, and (2) the short reviews of the "geological relations" by the chief geologists in the succeeding state reports.

Previous to Andrews's reports, however, some four or five references are made to a limetsone, which is believed to be the Maxville. These references are in the First and Second Annual State Reports, and appeared in the year 1838. The priority of these references necessitates their discussion first, although a presentation of Andrews's reports first would seem more appropriate.

1838.

Briggs, Jr., C. Report of. Geol. Surv. Ohio, First Ann. Rept., pp. 82, 83. 1838.

In this report the author states that: "At Reid's mill, ten miles from the former place (Jackson), is a sandy limestone, ten or twelve feet thick, which may belong to this stratum, although the question of its identity is not entirely settled. Here much of it is light colored and sandy, and unless closely examined would be passed by as sandstone (p. 82)."

Continuing, he says: "There remains to be mentioned another stratum of limestone, the relative position of which has not been determined. It occurs in the south or southwest part of Jackson County, on the land of John Canter. The whole stratum may be ten or twelve feet thick. The superior part is white, or nearly so, and is fissured in almost every direction. The lower part is subcrystalline, and, in some places, beautifully shaded with green and red (p. 83)."

Although in doubt as to the correct position of these limestones, he places them, at least tentatively, in the Coal Measures, for they, with others, are discussed under "Limestones" of the "Lower coal series." The Maxville occurs at both of these places, and the description fits it fairly well. For these reasons it is believed that these limestones and the Maxville are one and the same.

Briggs, Jr., C. Report of. Geol. Surv. Ohio, Second Ann. Rept., p. 135. 1838.

In the second report Briggs has, among others, a geological account of Hocking and Athens counties. In his description of the Coal Measure limestones he says: "The lowest stratum of limestone which was observed is in Hocking County, on Three Mile Run, Sec. 28, Green Township, a little more than a mile from the Hocking River and about three miles below Logan. It lies in layers from a few inches to a foot in thickness, the average depth of the stratum being from eight to nine feet. The upper portion, from three to four feet in thickness, is yellowish or buff colored, containing so much iron that it may perhaps be used as an iron ore. At any rate, the ferruginous matter will render it the more valuable for a flux. The lower layer is nearly white, and will make lime of a superior quality. It seems to be nearly pure carbonate of lime, and in places sub-crystalline and sufficiently compact to admit of a polish.

"* * * It can be seen to the best advantage in the southeast part of Perry County, at McCormick's Quarry, on Sec. 17, in the township before mentioned (Monday Creek). Here it is extensively quarried for the manufacture of lime. A new quarry has also been opened south of it on Sec. 20 (p. 135)."

The Maxville occurs at both of these places. At the former place nine feet and four inches are now exposed. At the latter it was formerly quite extensively burned for lime. It would seem that the limestone which Briggs described at both places is the Maxville.

1870.

Andrews, E. B. Report of Progress in the Second District. Geol. Surv. Ohio, Rept. Prog. in 1869, pp. 80-86. 1870.

As has already been stated, Andrews named, described and determined the geological position of the Maxville limestone. He says: "There is above the Logan sandstone group a limestone horizon, although the limestone is not everywhere persistent. It often gives place to sandstone of the usual coal measure grit. It was evidently formed on local basins occupied by quiet waters and cut off from the reach of the strong, sand-moving currents. But as these limestones group themselves upon one geological horizon, and always rest upon the top of the Logan sandstone group, I have no doubt that they have the same geological age and were formed at the same time. I have called it the *Maxville limestone* from the village of that name in Monday Creek Township, in Perry County, eight or ten miles northeast of Logan, where it has been extensively burned into quicklime (p. 80)."

As a second place of occurrence, Andrews refers on the same page to the quarry on the land of James Tonnihill, Section 28, Green Township, Hocking County. This is undoubtedly the limestone which Briggs found on Three Mile Creek a mile from the Hocking River.

Nothing was known of the limestone in any direction from this

place, except to the north. "It appears continuously northward for half a mile, and then is said not to be seen until within two miles of Maxville." Andrews states further that "south and west of the Hocking River it has not been noticed; but from recollections of explorations made by me several years since between Jackson and the Ohio River, I am led to think that in a few places I saw small developments of this limestone in its true geological horizon. *The same horizon, continued across the Ohio River, would strike the Sub-carboniferous limestone of Kentucky.* I shall be able, next season, to settle this important point." In a footnote at the bottom of the page he says: "This has subsequently been verified, and the *Maxville limestone* will probably prove to be the equivalent of the *Chester limestone* of the Illinois Reports (pp. 80, 81)."

After commenting on the limited extent of the limestone at Maxville, Andrews refers to a third basin, which is much larger than the other two. "Following the horizon of the Maxville limestone north through Perry County," he says, "we find the stone finely exhibited in Section 16, Madison Township, Perry County, on the land of Edward Danison. Here the waters of Jonathan Creek have excavated a deep channel, and the limestone, with perhaps fifty feet of the Logan sandstone, is exposed to view. * * * The limestone is from this point often seen in the valley, and is well exposed at Newtonville (now called White Cottage), Newton Township, Muskingum County, where it lies in the bed of the stream. At Newtonville and in the vicinity a fine collection of fossils was made from the limestones, all indicating the Sub-carboniferous character of the rocks (p. 82)."

1871.

Andrews, E. B. Lower Carboniferous Limestone in Ohio. Am. Jour. Sci., Vol. 1, pp. 91, 92. 1871.

To further substantiate his position with reference to the age of the Maxville, Andrews writes: "For several years I have suspected that a certain limestone in southeastern Ohio should be classed with those of the Lower Carboniferous limestones. The supposition was entirely contrary to the 'traditions of the elders,' and furthermore, the limestone was *above* the principal range of conglomerate which has been ever regarded as true Coal Measure conglomerate. In the prosecution of the Ohio Geological Survey in the Second District, entrusted to me, I find the conglomerate referred to is a Waverly conglomerate; that it is separated from the base of the productive Coal Measures by an upper Waverly sandstone group, rich in fossils, which I have called the *Logan sandstone group*, and that resting upon this group is, in many places, a limestone, called the *Maxville limestone*, which is a true Lower Carboniferous limestone. * * * The stratigraphical position of the limestone and the contained fossils led me to suspect that we had in it an Ohio representative of the Chester limestone of the Illinois Reports. This opinion has been confirmed (p. 91)."

He then gives the following "List of species and genera," by Meek:

1. Zaphrentis spc.
2. Scaphiocrinus decadactylus Hall ?
3. Productus pileiformis McChesney
4. Productus elegans N. and P.
5. Chonetes spc.
6. Athyris subquadrata Hall
7. Athyris trinuclea Hall
8. Spirifer (Martinia) contractus M. and W.
9. Spirifer spc.
10. Terebratula spc.
11. Aviculopecten spc.
12. Allorisma spc.
13. Naticopsis spc.
14. Straparollus perspectivus Swallow, spc.
15. Bellerophon sublævis Hall
16. Pleurotomaria spc.
17. Nautilus spc.
18. Nautilus spc.

Quoting farther from Meek's letter, Andrews adds, in part: "Of the 18 or 20 species of fossils sent from this rock, about one-half are represented in the collection only by specimens that are too imperfect for specific identification, though none of them, so far as their characters can be made out, appear to be allied to known forms from any horizon below the St. Louis limestone."

"Of the remaining species, five can be identified confidently with Chester forms, and three others are either identical with Chester species or most closely allied to forms of that age. Hence we may safely say that eight of the species are *Chester types*. Two, however, seem to be identical with species described from the St. Louis limestone farther west (p. 92)."

Andrews, E. B. Report of Labors in the Second Geological District. Geol. Surv. Ohio, Rept. Prog. in 1870, pp. 60-66. 1871.

Andrews reports the occurrence of the Maxville limestone at a number of new places in this survey report, which appeared subsequently to the above article in the Journal. He says: "In addition to the locations of this limestone in my district, mentioned in my last report, it is found on the Zanesville and Maysville turnpike, near the west line of Perry County; at Reed's Mill, one mile northeast of Hamden, Vinton County; near Enoch Canter's, Section 24, Hamilton Township, Jackson County, and on the Harrison Furnace lands, Section 24, Clay Township, and Section 7, Harrison Township, Scioto County (p. 65)."

With reference to the origin of the Maxville, he says, on page 91 of the Journal: "This limestone is not a continuous deposit, but has only a local development here and there, always resting, however, upon the

fine-grained Logan sandstone group. It was deposited in quiet basins along a uniform horizon. Generally there is an iron ore adhering to the top of the limestone. There is no evidence that the local deposits were once continuous and united and were subsequently separated by erosion."

This was followed, shortly after, by the following statement on page 62 of the 1870 Report: "It is more than probable that the Logan deposits, and with them the Maxville limestones, which were doubtless formed in depressions in the Logan, were brought up above the water, and remained for an indefinite period as a vast stretch of sandy flats. It is possible that during this period more or less surface erosion took place, but to what extent my observations thus far do not furnish data for a definite answer."

With the conditions for erosion so fresh in mind, it seems strange that Andrews did not consider erosion at least as one of the possible causes why the Maxville is found in isolated patches. A careful study of the above statements will show, however, that he considers the deposition in isolated basins as sufficient to explain the conditions.

1873.

Newberry, J. S. Geological Relations of Ohio. Geol. Surv. Ohio, Vol. I, Pt. 1, p. 73. 1873.

Andrews, E. B. Report of Muskingum County. Pp. 314, 315, 317, 319, 320, 321, 328, 345, 346.

In this report nothing new about the Maxville limestone was brought out. Only a casual reference to it is made by Newberry. A few similar references occur in Andrews's report. However, Andrews does state the other side of this question as to the origin of the stratum in the following sentence: "Whether the thin beds of the Maxville limestone were deposited before this erosion took place, and so shared in it as now to be left in isolated patches, or were deposited at first in limited basins, is as yet undetermined (pp. 345, 346)."

Newberry, J. S. Descriptions of Fossil Fishes. Geol. Surv. Ohio, Vol. I, pt. II, pp. 282, 283. 1873.

This part of Vol. I was devoted to Paleontology. Among other things, it contains descriptions and figures of fossil fishes by Newberry. "Fishes of the Sub-Carboniferous Limestone" is the somewhat imposing subtitle of some two pages of general discussion. That the basis for the discussion was principally the happy anticipation of a true scientist may be judged from the closing paragraph. It reads: "The exposures of the Carboniferous (sub) limestone in Ohio are few, and they have never yet been carefully searched for fish remains. It is to be expected, however, that some fishes will be obtained from them, and these are likely

to be those found in the upper or Chester subdivision, the only portion of the great western limestone mass that is represented in our state (p. 283)."

1874.

Newberry, J. S. The Carboniferous System. Geol. Surv. Ohio, Vol. II, Pt. I, pp. 99-103. 1874.

In this report Newberry devotes a few pages to the "Lower Carboniferous Limestone." In these he copies Meek's list of Maxville fossils, to which previous reference has been made. He seeks to qualify one of Meek's statements, but this seems unnecessary, since Newberry evidently misinterpreted the statement. A few general remarks are also made about conditions under which the "Lower Carboniferous" rocks of Ohio and adjacent states were laid down.

1875.

Andrews, E. B. Descriptions of Fossil Plants from the Coal Measures of Ohio. Geol. Surv. Ohio, Vol. II, Pt. II, pp. 415, 416. 1875

Only two casual references are made to the Maxville limestone. Although confined to two sentences, they are sufficient for Andrews to drive home his belief that the Maxville is the Ohio equivalent of the Chester limestone.

1878.

Read, M. C. Report on the Geology of the Hocking Valley Coal-Field. Geol. Surv. Ohio, Vol. III, pp. 653-655, and 712. 1878.

Newberry, J. S. Review of the Geological Structure of Ohio. Geol. Surv. Ohio, Vol. III, pp. 23-25. 1878.

Orton, Edward. Supplemental Report on the Geology of the Hanging Rock District. Geol. Surv. Ohio, Vol. III, pp. 883, 888, op. p. 889, pp. 889-891, op. p. 912, pp. 921, 933. 1878.

Andrews, E. B. Supplemental Report on Perry County, and Portions of Hocking and Athens Counties. Geol. Surv. Ohio, Vol. III, pp. 817-824. 1878.

In this volume the Maxville limestone receives more than the usual amount of attention. Read gives a "Section of Rocks about Shawnee," in which the Maxville is shown at its proper horizon. Some three or four references are subsequently made to the formation, and in each case it is mentioned as occurring to the west, in the vicinity of Webb's Summit and Maxville. The important references occur, however, in the controversy between Orton and Newberry on the one hand and Andrews on the other. Since the stratigraphical position which Andrews assigned to the Maxville and adjacent rocks was questioned by both of the other men, the discussion will be given somewhat in detail.

Newberry, in his "Review of Geological Structure," states that: "Prof. Edward Orton, who has been engaged during the past summer in a careful review of the geology of the Hocking Valley region, has brought out some new facts in regard to the Maxwell limestone which will give it fresh interest to geologists, while at the same time they explain

in an unexpected way all the mysteries that have hung around it. These facts are briefly as follows: 1. That the Maxville limestone can be followed by numerous outcrops as a distinct geological horizon from Perry County to the Ohio River, and that it does not lie in patches alternating with others of conglomerate, as has been represented. 2. That one, sometimes two, limestones or flints are found within a hundred feet below it, which share in a degree its lithological character and fossils. 3. That the Wellston and Jackson coals, well known and important seams in southern Ohio, are both beneath the Maxville limestone.

"A recent visit to the Hocking Valley, in company with Prof. Orton, has resulted in the verification of all his observations, and the collection of fossils from the Maxville limestone and Waverly shales, which prove beyond question that the lower coals, two or three in number, of southern Ohio are of Lower Carboniferous age.

"Another important result of the recent observations of Prof. Orton is to demonstrate that all the conglomerate of southern Ohio lies below the Maxville limestone, and is therefore distinct from and older than the conglomerate of northern Ohio. The latter conclusion, which will, perhaps, be questioned, is established by the facts that the conglomerate of southern Ohio is overlain by shales, which contain the fossils characteristic of the Upper Waverly in Holmes, Summit, Mahoning, etc.; while the conglomerate of northern Ohio—which, apparently, extends no further south than Licking County, and thence thickens greatly northward—lies upon the Upper Waverly, and has no Waverly fossils in or above it (pp. 24, 25)."

These statements seem to be just a trifle more sweeping than those in Orton's letter, which accompanied the latter's report to the Chief Geologist, Newberry. In this letter Orton gives the following conclusions:

"1. The conglomerate of Pike and Jackson counties, which holds within it workable coal, is the conglomerate (Black Hand) of the Hocking Valley, which has been proved to be of Sub-carboniferous age. There are several divisions of this Conglomerate, but they are all included within two hundred feet of vertical range, and they all belong to one main series.

"2. The Jackson Shaft Coal belongs within the limits of this conglomerate, and is therefore of Sub-carboniferous age. The same thing is probably true of several other workable coal seams of the district.

"3. The Maxville limestone does not constitute the base of the Coal Measures of southern Ohio, but its place is from fifty to one hundred feet above the lowest coal seams. The Sub-carboniferous age of the limestone is not hereby questioned, but the same age is asserted for the lowest Coal Measures of this district (p. 883)."

In the report proper Orton says: "The horizon of the Maxville limestone can apparently be followed in patches of gray or drab, some-

times bluish, limestones, generally sandy in composition, from the south line of Vinton County, through the townships of Lick, Franklin and Hamilton, of Jackson County, and through Harrison and (——————) townships, (of) Scioto County, to the Ohio River. In other words, the Maxville limestone constitutes a definite horizon in the Lower Coal Measures. It may be described as an *intra-conglomerate* limestone. The main body of the conglomerate, the Waverly conglomerate of Prof. Andrews, lies below it, but in the southern part of the district it is also overlain in some instances by twenty or thirty feet of conglomerate (p. 891)."

From this it is seen that Orton's published claims of the distribution of the Maxville limestone are not so great as Newberry reported above. The northern limit is Vinton instead of Perry County, while the southern is the same in either case. To what limestone in Lick and Franklin townships, Jackson County, Orton referred, is not known, but it must have been one of the limestones belonging to the Pennsylvanian series.

A chart of the "Coal Seams of the Hanging Rock District" is given in which the position of the limestones is also shown (op. p. 912). Another chart, "General Section, Showing Order of Succession of Coals, Ores and Limestones in the Hanging Rock District," as its name indicates, shows all of the rocks (op. p. 921). In both charts the Maxville is placed above the Jackson Shaft and Wellston coals. "Combined Sections from Vicinity of Hamden Junction, Vinton County, by Dr. L. W. Baker," is the title of still another chart published by Orton in this same report (op. p. 933). All of the strata are given in this section. The Maxville limestone is shown well up in the Pennsylvanian series with two or three coals below.

In this report Andrews firmly defends the position and age assigned to the Maxville limestone. He says: "The Maxville limestone rests upon the Waverly, and its deposition marked a new era in geological history. It is no part of the Waverly series, and has nothing in common with the Productive Coal Measures. As the last statement has recently been questioned by my associate, President Orton, who has expressed to me and to others his strong belief that the Maxville limestone is one of the regular Coal Measure limestones, having its true place about one hundred feet above the base of the Coal Measures, I shall be expected to give the reasons for the conclusions reached during the progress of the Survey and which I firmly hold (p. 817)."

After the seven places of occurrence are mentioned, the limestone is briefly described at each one. When the rocks are shown above and below, attention is always called to this fact and that these are the "Coal Measures" and Logan respectively. The "Lower Carboniferous" position of the Maxville is thus clearly shown.

Near the close of the discussion Andrews states that: "In the report for 1869 it was suggested that these areas of Maxville limestone may

represent local basins in which the limestone was deposited. This may have been wrong, for it is quite possible that in the original deposition the areas were connected and the formation continuous. After deposition, large areas of it might have been removed with much of the Waverly before the beds of the Coal Measure rocks were laid down. This would leave valleys between the remnants of the Maxville limestone series. The subject of the erosion of the Waverly and consequent uneven character of the floor on which the Coal Measures rest, has often been referred to in the Ohio Reports, and by different persons. In the report of Holmes County, in the present volume, Mr. M. C. Read gives, on page 544, an interesting illustration of this. Waverly rocks, capped with Conglomerate, are seen on one side of a hill, while on the other there are one hundred and ninety-eight feet of Coal Measures, including five seams of coal. There was evidently an ancient valley in the old Waverly in which the Coal Measures were formed. Proofs of similar valleys in regions adjacent to deposits of the Maxville limestone were long since observed. Of course the levels of the coals in them, if continued, would pass below the level of the limestone; *but in no case have any rocks of the true Coal Measures been found directly underneath any of the limestone of the Maxville series*, and I do not believe that such a case is possible (pp. 821, 822)."

In the above paragraph Andrews admits that his idea that "the areas of Maxville limestone may represent local basins in which the limestone was deposited," may have been wrong. To take its place, he suggests the possibility of an original continuous deposit, later separated by erosion. The latter hypothesis is not proven, for the instances of erosion cited could have taken place as well before the Maxville age as after it. The statement only shows his readiness to accept proof that the separate patches are due to erosion. The uppermost thought in his mind was to prove that although there were coals below the *level* of the Maxville limestone, yet none occurred underneath it, as Orton so unfortunately claimed.

1879.

Andrews, E. B. Discovery of a New Group of Lower Carboniferous Rocks in Southeastern Ohio. Am. Jour. Sci., Vol. XVIII, p. 137. 1879.

Andrews reports the discovery in Perry County of a group of fossiliferous rocks between the Maxville limestone and the Waverly. From the fauna it is inferred that the group is approximately the equivalent of the Keokuk in age. The exact place of occurrence is not given, but, since the term Rushville was proposed for the group, the exposure is probably near the town of that name. A section is shown in which the Maxville limestone occurs at the top and is estimated to be from 15 to 18 feet in thickness.

Newberry, J. S., Chief Geologist; Andrews, E. B.; Orton, Edward; Read, M. C.; Gilbert, G. K.; Winchell, N. H., and Hill, F. C., Assistant Geologists. Geological Map of the State of Ohio. Geol. Surv. Ohio. 1879.

With the exception of a small area at Zanesville, the Lower Carboniferous limestone horizon is shown on this map as extending continuously from Dresden to the Ohio River.

Geological Atlas of the State of Ohio (Review). Am. Jour. Sci., Vol. XVIII, p. 410, 1879.

From the following quotation it will be seen that Andrews objected rather strenuously to the Maxville limestone appearing as a continuous formation on a map a part of the work of which was credited to him. "Some points in the details of the part of the map relating to the section of the state under the charge of Professor E. B. Andrews are not in accordance with his conclusions; and since he had no part personally, as he states, in the preparation of the map, his proposed corrections, recently received for this Journal, are here annexed (Newberry, p. 410).

"(1) The Lower Carboniferous limestone—the Maxville limestone of my reports—is represented on the map as having a continuous outcrop, forming, with but a single short break, a continuous belt more than four hundred miles long around the sinuous margin of the Coal Measures. In my investigations in this district, where I have long lived, I have found the Lower Carboniferous limestone only in a few localities mentioned in the Reports, and always in limited patches. The limestone belt of the map crosses the paths of Professor Orton in Pike County, Professor M. C. Read in Licking County and Professor Stevenson in Muskingum (northern), but none of these field-workers saw it, and their detailed geological sections give no hint of it. (2) The Conglomerate at the base of the Coal Measures reported by Professor Orton in Pike County and by myself in Jackson County is omitted from the map (Andrews, p. 410)."

1880.

Orton, Edward. Review of Certain Points in the Geology of Eastern Ohio. Ann. Rept. Sec'y State for 1879, pp. 612, 613. 1880.

In this report the Maxville limestone is made a member of a group which consists of limestone, flint, fire-clay, coal and other "Coal Measure" rocks. After referring to his statements about the Maxville limestone in Volume III, Orton says: "I have never discussed this formation formally, but I am obliged to confess that in what I have said of it incidentally, and in what I have represented in sections accompanying my reports, I have incorporated several considerable errors. I regret these errors all the more because my friends have been, in some instances, misled by them in publications that they have made. I refer especially to Prof. Newberry's statements in Vol. III, Geol. of Ohio. The errors to which I refer consist in placing the Wellston coal below the Maxville limestone and the Jackson coal 100 feet below the same horizon. I am now satisfied that the Wellston coal belongs above the Maxville group,

and the conglomerate as well, and I am not sure that the Jackson coal lies below (pp. 612, 613)."

1882.

Whitfield, R. P. Descriptions of New Species of Fossils from Ohio, with Remarks on Some of the Geological Formations in Which They Occur. Annals New York Acad. Sci., Vol. II, pp. 219-226. 1882.

The fossils described in this paper were not illustrated, but each species was referred to a certain figure and plate in Volume III of the Paleontology of Ohio. This volume was to appear later, and in it the original descriptions were to be reprinted. The volume was, however, never printed.

The new species included eleven from the Maxville limestone, the "equivalent to the Chester limestone or Chester and St. Louis limestones." They are:

1. Cyathocrinus inequidactylus
2. Synocladia rectistyla
3. Pinna maxvillensis
4. Allorisma andrewsi
5. Allorisma maxvillensis
6. Naticopsis zic-zac
7. Holopea newtonensis
8. Macrocheilus subcorpulentus
9. Polyphemopsis melanoides
10. Bellerophon alternodosus
11. Nautilus pauper.

1884.

Orton, Edward. The Stratigraphical Order of the Lower Coal Measures of Ohio. Geol. Surv. Ohio, Vol. V, p. 99, 117. 1884.

Orton, in this report, gives a section of Jonathan Creek, in which the Maxville limestone is placed at the base of the section and below the "Coal Measures." The stratum is also referred to the Sub-carboniferous horizon (p. 99). Later in the report he says: "The stratigraphical order of the Hanging Rock District was in the main clearly shown in my report upon that field in Volume III, Geology of Ohio. The general section there published has proved a true one for almost every portion of the series, and has become an accepted guide in the practical development of the region. An error of some magnitude, and very confusing to the true order, is, however, to be found in the position assigned to the Maxville limestone. This limestone is undoubtedly of Sub-carboniferous age, and is geologically below both the Wellston and Jackson coals, whereas the section reverses this true order. The view so strenuously maintained by Andrews in regard to this point was the true one (p. 117)."

Hawes, George W. Building Stones of Ohio. Geol. Surv. Ohio, Vol. V pp. 578, 137 (637). 1884.

In this report of Hawes it is not quite clear whether the author places the Maxville limestone within the limits of the Waverly or not (p. 578). If he intended so to do he has departed from the usual methods. He also refers to the fine Muskingum County court house, which was built of limestone from this formation quarried at Newtonville (p. 137 should be 637, p. 638).

Orton, Edward. The Coal Seams of the Lower Coal Measures of Ohio. Geol. Surv. Ohio, Vol. V, pp. 869, 885, 991, 1009 and 1010. 1884.

The author refers to the Newtonville limestone of Chester limestone age as occurring near Uniontown (Fultonham), Muskingum County (p. 869). The term "Newtonville" is simply a synonym that is sometimes used instead of the Maxville. A slight reference is also made to the Maxville under the subheading, "Coal Mines of Perry County" (p.885). Under the title "The Hocking Valley Coal Field," Orton says: "The horizon (Sharon) is well marked, even when the coal is wanting, the Maxville limestone (Sub-carboniferous) or its clay, ore or flint being often found at nearly the same level (p. 991)." For reasons which will be presented later in the stratigraphical division of the present paper, it is not best to speak of the Maxville group as consisting of clay, ore or flint as well as of limestone. These rocks other than the limestone belong to a distinct and later date.

Under "Mines of Jackson County," we are pleased to hear Orton say: "The several conglomerates that occur in this general field are in fact one source of the confusion that prevails as to the true order. The Waverly (Black Hand) conglomerate is in strong force within this district. There are, besides, the conglomerate below and the one above the Jackson Shaft coal. As has been abundantly proved, the Carboniferous Conglomerate can no longer be counted an undivided stratum, but it is rather a complex and much varied formation. There is no single stratum of pebble rock in the state that has any longer a right to be called 'the Conglomerate.' " "In my report upon the Hanging Rock District in 1877, Vol. III, page 885, a mischievous and confusing error appears in all of the sections involving this part of the scale. The Jackson Shaft coal and the Wellston coal are represented as lying below the Maxville limestone. The real order is given in the preceding statement (pp. 1009, 1010)."

1886.

Orton, Edward. The Geological Scale of Ohio. Geol. Surv. Ohio, Prelim. Rept. Petroleum and Inflammable Gas, pp. 17, 26. 1886.

In this report the "Sub-carboniferous" limestone is given at its proper horizon. Mention is also made of its occurrence under cover in many drillings in the Ohio Valley, without locating the wells.

1887.

Orton, Edwa d. The Geological Scale of Ohio. Geol. Surv. Ohio, Prelim. Rept. Petroleum and Inflammable Gas. Reprinted for the author, with a supplement by A. H. Smythe, pp. 26, 39. 1887.

As the title indicates, this is a reprint of the previous volume, with a supplement, in the latter of which the Maxville is not mentioned.

Herrick, C. L. A Sketch of the Geological History of Licking County. Bull. Sci. Lab. Denison Univ., Vol. II, pp. 14, 15. 1887.

The Maxville limestone is shown in a number of sections in a plate of "Grouped Sections from Granville to Newton." The presence of the stratum near water level from Newton to near Mt. Perry is also mentioned.

1888.

Orton, Edward. The Geology of Ohio Considered in Its Relations to Petroleum and Natural Gas. Geol. Surv. Ohio, Vol. VI, p. 3, op. p. 4, and p. 42. 1888.

The Maxville limestone is placed at its proper horizon in both the geological scale and in the vertical section. Speaking of the stratum, Orton says: "The limestone is found in outcrop in Scioto, Jackson, Hocking, Perry and Muskingum counties. It is reported in the well records of Steubenville, Brilliant, Macksburg and at several other points in the Ohio Valley (p. 42)."

Orton, Edward. The Berea Grit as a Source of Oil and Gas in Ohio. Geol. Surv. Ohio, Vol. VI, pp. 321, 327 and 405. 1888.

In the "general order" of the strata in the wells of the Macksburg oil-field (p. 321) the Maxville limestone is not shown, although it was mentioned above as occurring there. No record of the well at Brilliant is published. The record of the Jefferson Iron Works well at Steubenville shows a limestone fifty feet in thickness, which is referred to as the "Sub-carboniferous" limestone (p. 337). Speaking of the limestone which occurs in the Laughlin well at Martin's Ferry, Orton says: "The record can be interpreted with but little difficulty, the Sub-carboniferous limestone, which was found at a depth of 845 feet, proving a great help in this work of classification (p. 405)."

Orton, Edward. The Production of Lime in Ohio. Geol. Surv. Ohio, Vol. VI, p. 707. 1888.

The author refers to the variability in composition of the Maxville limestone. This undoubtedly is due to a great extent in comparing the

lower half of the stratum as exposed at one place with the upper half at another.

Herrick, C. L. The Geology of Licking County, Ohio; Part IV, The Subcarboniferous and Waverly Groups. Bull. Sci. Lab. Denison Univ., Vol. III, Pt. I, pp.20-23, 1888.

The author says: "The next link in the series connecting the coal measures and the Waverly is found in the so-called Maxville or Chester limestone. A considerable fauna will yet be restored to us by a sufficiently prolonged search in the limestones and shales of this series in Ohio, which is nearly 25 feet thick in the vicinity of Fultonham. Eleven species have been described from this horizon by Whitfield. The characteristic species which are everywhere abundant are *Productus parvus*, which, however, is often much larger than the type, and approaches P. semireticulatus in some characters, *Spirifer glaber*, *Athyris subtilita*; *Euomphalus planodorsatus and Bellerophon* sp., *Pleurotomaria chesterensis* (?), *Holopea newtonensis* (?), *Nautilus spectabilis*, *Ctenodonta* (?) sp., *Allorisma andrewsi* (Plate XIII, Fig. 12) and *Spirifer increbescens*, H. With regard to the last-mentioned species, it may be here noted that no difficulty exists in tracing this species to its successor in the coal measures (S. opimus), and to its probable progenitor in the St. Louis group (S. Keokuk var. Hall), this in turn to the Keokuk group. There are many hints of this sort which will occur to the attentive student of these successive faunae. A cup coral, Lophophyllum sp. (?) (see Plate XIII, Fig. 17), also occurs rarely (p. 20)."

The two references to Plate XIII of Volume III are incorrect. They should be to Plate XI; and since this plate was accidentally omitted from Volume III, they should be to Plate XI of Volume IV. The statement of the abundance of the characteristic species is also decidedly misleading.

In the description of *Nautilis* (?) *bisulcatus*, sp. n., Herrick says: "N. pauper, Whitfield may prove identical with our form, but it would not be suspected except from incidental similarities, and the fact that our form is derived from the same horizon at Fultonham (p. 21)."

In this description the reference to "Plate XI, Fig. 16" should also be to Volume IV instead of Volume III.

After giving a section from a point two or three miles west of Fultonham, Herrick says: "No unconformity could be detected between the shales forming here the base of the coal-measures and the reddish layers, which are undoubtedly Waverly and contain *Chonetes illinoisensis* and other characteristic fossils (p. 21)."

Later: "While conformity between the upper Waverly and lower Chester does not exclude the idea of a considerable interval of time between the fossiliferous bands of the two groups, it is apparent that in Licking County the Chester interval is unrepresented and that much of

the upper Waverly is generally absent, so that the white sandstone or conglomerate of the coal-measures lies unconformably on one or other of the Waverly beds and the upper surface of the Waverly itself has obviously suffered erosion. The amount of the erosion varied in different places, and where greatest is covered by coarse quartz pebbles of granitic origin mingled with coal-measure trees of large size. The suggestion of extensive erosion (has) been heretofore made, but absolute proof has been wanting. It is our privilege to complete the evidence and to point out in general the amount of loss thus incurred. It has been quite generally supposed that an elevation of the coast at the close of the Waverly period caused the recession of the water, and that the period occupied at the west by the deposition of some 550 feet of sediments was not a time of rock formation in central Ohio. The results of close study of the lowest coal-measure conglomerate has unexpectedly indicated the contrary. While engaged in collecting samples of the quartz pebbles forming the bulk of this conglomerate eight miles northeast of Newark, a large number of fragments of limestone were also broken out. These are angular, and, though very badly decomposed, show that they could not have been derived from a distance, as the quartz must have been in order to free itself so fully of the softer, including the country rock, and acquire its rounded form, and moreover, they contained a few fossils which can only be referred to the age of the Chester or St. Louis group. These conglomerates are full of the impressions of Lepidodendrids and Calamites, and seem to have been torn from their places by torrents which carried from the mountains to the north their freight of coarser and finer material, much of it being of a metamorphic and igneous nature. The Chester limestone must at that time have been more or less firmly consolidated, perhaps in the form of clods of limy clay, and has preserved identifiable remains to tell the story. Thus the same coarse conglomerate tells us that a mighty river flowed into the coal-measures ocean from a region to the north, exposing igneous and metamorphic (partly granitic) rock, that it flowed through a region covered by deposits of St. Louis or Chester age, thus showing that a large series supposed to be absent in this part of the state was simply obliterated by erosion (pp. 22, 23)."

Herrick's interpretation of erosion and consequent unconformity is probably correct. But that he should have overlooked the proof positive in the Fultonham region, and accepted the vaguer paleontological evidence, seems strange. Especially is this true when it is stated that more or less of the lime in the angular blocks of the Sharon conglomerate has been replaced by silica, and that the fossils are in such an extremely poor state of preservation that positive identification is practically impossible.

Herrick, C. L. Geology of Licking County. Ohio; Part IV, Waverly Group, Continued. Bull. Denison Univ., Vol. IV, Pt. I, p. 122, pl. XI. 1888.

Plate XI is the one that was accidental y omitted from Volume III. It contains the following figures of fossils from the Maxville stratum:

Fig. 11. Productus parvus. Chester limestone.
Fig. 12. Allorisma andrewsi. Chester limestone.
Fig. 14. Spirifer increbescens. Chester limestone.
Fig. 15. Spirifer glaber. Chester limestone.
Fig. 16. Nautilus bisulcatus. Her. Chester limestone.
Fig. 17. Lophophyllum sp Chester limestone.
Fig. 23. Spirifer increbescens. From limestone fragments in coal measure conglomerate in Licking County.

With the exception of the figure of *Nautilus bisulcatus*, the description of which appeared in Volume III, these figures are not accompanied by descriptions. As a result there is some uncertainty as to the correctness of at least some of the identifications. Weller has referred *Spirifer glaber* to *Martinia contracta*, and the writer *Spirifer increbescens* to *Spirifer keokuk*. Herrick himself admitted that *Nautilus bisulcatus* may prove identical with Whitfield's *Nautilus pauper*. It seems probable that *Productus parvus* and *Lophophyllum* sp. may also prove identical with *Productus cestriensis* and *Zaphrentis* sp., respectively.

1890.

Orton, Edward. Geological Scale and Geological Structure of Ohio. Geol. Surv. Ohio, First Ann. Rept. (3rd organization), op. p. 9, and pp. 42, 43. 1890.

The portion which treats of the Maxville limestone in this report was copied from a similar portion, op. p. 4 and 42, of Volume VI.

1891.

Whitfield, R. P. Species from the Maxville Limestone, the Equivalent of the St. Louis and Chester Limestones of the Mississippi Valley. Annals New York Acad. Sci., Vol. V, pp. 576-595 and pls. XIII and XIV. 1891.

Since Part II, Paleontology, of Volume III was not printed, as has already been stated, the new fossils described by Whitfield in 1882 failed to be illustrated. In this 1891 report, however, the descriptions of the eleven new forms from the Maxville are reprinted from the 1882 report and are accompanied by illustrations. To these eleven are added the descriptions and figures of all of the other known forms, even though they had already been so treated. This addition was:

Zaphrentis cliffordana
Pentremites elegans
Polypora varsouviensis ?
Streptorhynchus crassum
Productus elegans
Productus pileiformis
Spirifera (Martinia) contractus
Spirifera rockymontana ?

Athyris subquadrata
Terebratula turgida
Schizodus chesterensis
Straparollus similis
Bellerophon sublævis ?
Nautilus (Temnocheilus) spectabilis

1893.

Orton, Edward. Geological Scale and Geological Structure of Ohio. Geol. Surv. Ohio, Vol. VII, Pt. I, p. 4 op. p. 4, and pp. 35, 36. 1893.

This part (Part I) of Volume VII was later bound with Part II to form the complete volume of 1894. Since the description of the "Sub-carboniferous" or Maxville limestone in Part I is practically a copy of that which appeared in Volume VI, it is not necessary to discuss this description now or to refer to it again when Volume VII as a whole is abstracted.

1894.

Whitfield, R. P. Species from the Maxville Limestone, the Equivalent of the St. Louis and Chester Limestones of the Mississippi Valley. Geol. Surv. Ohio, Vol. VII, Pt. II, pp. 465-481, pls. IX. X. 1894.

These descriptions and illustrations of the Maxville limestone are exact copies of the ones that appeared in Volume V of the Annals of the New York Academy of Sciences.

1897.

Weller, Stuart. The Batesville Sandstone of Arkansas. Trans. N. Y. Acad. Sci., Vol. XVI, pp. 251-282 and pls.

In this report Weller describes a number of new species from the Batesville sandstone. From both the paleontologic and stratigraphic evidence he pronounces the Batesville and the Aux Vases (Cypress) sandstone to be definite equivalents, and he states that "The paleontologic evidence also points to the equivalence of the Batesville sandstone and the Maxville limestone of Ohio (p. 282)."

1902.

Martzolff, Clement L. History of Perry County, Ohio. Ward & Weiland, New Lexington, Ohio, pp 5, 6, 18 and 19. 1902.

In this report Martzolff says: "At McCuneville the Sub-carboniferous limestone is one hundred and ten feet beneath the creek bed (pp. 5, 6)." Later he gives a "Section of Rock at McCuneville" (pp. 18, 19), the lower part of which is from a salt well and includes the Maxville limestone. The section is credited to the Ohio Geological Report, but to which one is not stated. His "List of Fossils from the Maxville Limestone" consists of eighteen species. The list agrees, in its entirety, with Meek's list, which Andrews published in Volume I of the American Journal of Science and in the 'Report of Progress' in 1870, and to both of which reference has already been made.

Stevenson, John J. Notes on the Mauch Chunk of Pennsylvania. Am Geol., Vol. XXIX, pp. 242-249 1902.

In this paper Stevenson has shown that the names Vespertine and Umbral, which H. D. Rogers applied to the lower and upper halves of the Mississippian rocks in Pennsylvania, were rejected, and replaced by Pocono and Mauch Chunk, by Lesley; and that the Mauch Chunk consists of three zones, shales, limestones, and shales, in the northern portion of the state, whereas it consists of only two, limestones and the upper shales, in the southern part, and that the United States and Maryland surveys have applied the terms Greenbrier and Mauch Chunk, respectively, to the limestone and upper shales of the original Mauch Chunk. These changes are shown more clearly in the following table:

H. D. Rogers	Lesley	Northern Penn.	Southern Penn. and to the south	United States and Maryland Surveys
Umbral	Mauch Chunk	shales limestones shales	shales limestones (shales, wanting)	Mauch Chunk Greenbrier
Vespertine	Pocono			Pocono

The limestones (Greenbrier) are, furthermore, shown by Stevenson to be made up of a lower siliceous limestone which is barren of fossils and an upper limestone which is much purer and very fossiliferous. From a rather extensive collection of fossils from this upper limestone, which Stevenson sent to him, Weller was enabled to pronounce the fauna as practically identical with that of the Maxville of Ohio as described by Whitfield in Volume VII of the Ohio Reports.

1903.

Stevenson, John J. Lower Carboniferous of the Appalachian Basin. Bull. Geol. Soc. Am., Vol. XIV, pp. 15-96, 1903.

In this subsequent report Stevenson has made some radical changes from the original classification of the Mississippian rocks of the Appalachian basin. The greater portion of the Pocono shales have had their old name supplanted by the term Logan, which the author, in following Herrick and Orton, has so expanded that it includes in Ohio not only the Logan, but at least the Black Hand as well, a usage not sanctioned by the later workers. Tuscumbia is adopted to cover the lower portion, siliceous limestone, of the Greenbrier and the shales just beneath which form one of the three subdivisions of the original Mauch Chunk and which are found only in northern Pennsylvania. For the upper portion—that is, the purer, fossiliferous limestone—of the Greenbrier, the term Max-

ville is adopted. The name Mauch Chunk as used in the restricted sense is replaced by the term Shenango. These changes can also be shown more clearly in a table:

United States and Maryland Surveys	Stevenson
Mauch Chunk........	Shenango
Greenbrier {pure	Maxville.
Greenbrier {siliceous .... shales	Tuscumbia
Pocono	{Logan
	{.........

Bownocker, John Adams. The Occurrence and Exploitation of Petro leum and Natural Gas in Ohio. Geol. Surv. Ohio, Bull. I. 1903.

In this report it is said that the Maxville limestone is known to the driller as the "Mountain lime" or "Big lime" (p. 24). Under one or the other of these names a limestone occurs in the well records at a number of different places. These will now be given.

Wells in which the Maxville is reported:

	Thickness in feet.	Page.
McConnellsville Fair Ground, Morgan County.....	44	145
Mead farm, Washington County................	35	185
Hohman Pool, Ludlow Township, generalized, Washington County......................	50	188
Lucas Farm, Washington County	150 (?)	190
Germantown Pool, Liberty Township, generalized, Washington County......................	0–20	192
G. Carpenter Well No. 1, Monroe County	35	196
J. R. Diest farm, Monroe County	60	196, 197
George Keller farm, Monroe County	134	201
Graysville Pool, generalized, Monroe County	60–100	204
J. Dearth farm, Monroe County.................	60	205–206
G. W. Martin farm, Monroe County	67	208
Holtsclaw well, Monroe County	40	210
F. C. Newhart well, Monroe County	36	212, 213
Longshore farm, Muskingum County	40	267

1904.

Orton, Jr., Edward, and Peppel, S. V. The Lime Resources of Ohio Available for Portland Cement Manufacture. Geol. Surv. Ohio, Bull. 3, p. 90. 1904.

Orton and Peppel assign the Maxville limestone to a position at the base of the Coal Measures and just above the "Sub-carboniferous" without stating their reasons. In reference to its origin they say: "It appears to have been deposited in lakes or ponds of limited area." This

statement is also incorrect, since the fossils of the limestone are of marine origin. Its most southern exposure is given as two and a half miles below Logan, whereas it is found in Vinton, Jackson and Scioto counties.

1906.

Orton, Jr., Edward. The Composition of the Limestones of Ohio, with Special Reference to Their Fitness for Portland Cement Manufacture, Considered by Counties. Geol. Surv. Ohio, Bull. 4, op. p. 31. and pp. 79, 82, 85, 88, 92, 105, 113-115, 122 and 126. 1906.

This report is accompanied by a map showing the principal limestone formations of the state. The "area in which the Maxville limestone may be expected" covers a part of Licking, Muskingum, Perry and Hocking counties (op. p. 31).

Under the heading of "Hocking County," Orton corrects his former error, and refers the Maxville to the "Sub-carboniferous" rather than to the Coal Measures. Speaking of its irregularity, he says: "It seems to be eminently a pocket, or lake bed formation, as it can be found only here and there inside the area represented by its outermost deposits. When found, these different deposits manifest wide differences in composition, thickness and lithological structure, greater than would be apt to be the case in a continuous stratum in so short a distance (p. 79)." "Its southernmost known deposit" is again given as two and a half miles southeast of Logan. These statements in reference to the irregularity, difference in composition and southern limit of the stratum have already been discussed, and need no further comment save perhaps the one in reference to the differences in composition. This variability in composition is undoubtedly due in a great degree to the comparing of the limestone of one-half of the stratum at one place with that of the other half at another locality.

Under the title of "Jackson County," the author says: "The Maxville has never been found (p. 82)." This seems to be an oversight. It will be recalled that Andrews reported as early as 1871 the Maxville as occurring near Enoch Canter's, Hamilton Township.

In "Lawrence County" the Lower Mercer is given as the lowest limestone. He says: "This limestone, or the Maxville, was encountered at Olive Furnace in a bore hole two hundred feet beneath the surface. The core removed was almost white, exceedingly dense, and a very pure carbonate of lime. The thickness was reported about twelve feet (p. 85)."

Speaking of Bowling Green, Franklin and Hopewell townships in "Licking County," he says: "In this vicinity the Maxville limestone is due, and is reported to have been found and worked for road metal in 1832 and 1835 for construction of the National Road to Columbus. Whether these old quarries came into Licking County is not known, but in any case they are not believed to represent a thick or important ex-

tension of the Maxville field. Nothing can be found of this formation in the gorge of the Licking River, eight or nine miles north (p. 88)."

Discussing the formations of "Mahoning County," the author says: "The Pottsville formation forms the floor on the north; Coal No. 1, at the bottom of the coal measures, was found in pockets around Youngstown and exhausted long ago. * * * The Maxville is missing (p. 92)."

Under "Muskingum County" the author says: "Mr. A. J. Hoover, of the Fultonham Brick Company, has drilled through the stone in several places in search of an artesian water supply. He reports the stone as variable, being cut out in spots, and present in points only one hundred feet or so distant. The thickness at the points drilled was about forty-five feet (p. 105)."

Under "Perry County" the author gives a section and an analysis of the Maxville as found on the land of David Hendricks, near Maxville, and discusses its fitness for a cement stone (pp. 113, 114). Analyses of samples from Section 25, Reading Township, and from near Fultonham, are also given (p. 114). Farther on the author says: "It has been quarried here (Glenford) for furnace flux, and for road materials during the 1830's, while the Maysville Pike or National Road was being put through this section. These old workings were long since abandoned, and are now so filled up that samples could not be gotten (p. 115)."

Speaking of the limestones of "Scioto County," Orton says: "The Maxville, due at the bottom of the coal measures, is represented locally by a flint fire clay of great purity. This formation occurs in basins or pockets, just as the Maxville limestone is suspected of doing. The latter is sparingly represented, if at all, by nuggets or bowlders of limestone occurring imbedded in clayey strata (p. 122)." Andrews, it will be recalled, reported this limestone on the Harrison Furnace lands, where it was mined for furnace flux. Under the heading of "Stark County" the author says: "The horizon of No. 1 Coal at Massillon is not characterized by any development of the Maxville limestone stratum (p. 126)."

Orton, Jr., Edward, and Peppel, Samuel Vernon. The Composition, Physical Character and Uses of the Limestones of Ohio, Considered by Geological Formations. Geol. Surv. Ohio, Bull. 4, pp. 168-172. 1906.

As the title suggests, the previous information appearing under the separate county headings is here assembled under that of the respective formations. At the close of the discussion on "The Maxville Limestone" the following note appears: "Since writing the foregoing some points have been raised which render the classification of the Fultonham stone as of Maxville age somewhat less certain than it had been regarded previously. The question is one of interest to stratigraphical geologists primarily. No abatement need be made in the statements regard-

ing the quantity or character of this stone, but it is barely possible that as a result of the investigations which will now be given to it that it may be found to be wrongly named, and that it may be Mercer in age instead of Maxville (p. 172)."

The stratigraphical portion of the present paper shows that the Fultonham stone is undoubtedly of Maxville age.

SUMMARY.

As early as 1838 Briggs described a limestone at Reed's Mill ten miles from Jackson, on the land of John Canter in Jackson County, on Three Mile Run near Logan, and in southern Perry County, and referred it to the Coal Measures, but the limestone is undoubtedly the Maxville, and hence belongs to the Mississippian series.

Andrews, in 1870, was the first to name, describe, and correctly refer the Maxville limestone to the Mississippian series. He studied the stone at three places, at Maxville, on Three Mile Run, and on Jonathan Creek, noted its occurrence in isolated patches, and accounted for this isolation by attributing its origin to deposition in local basins.

In 1871 Andrews published Meek's list of fossils, which confirmed the former's belief in the Chester age of the Maxville, and mentioned the limestone as occurring at a number of new localities—namely, in western Perry County, at Reed's Mill, near Enoch Canter's in Jackson County, and on the Harrison Furnace Lands in Scioto County.

In 1873 Andrews was ready to say that: "Whether the thin beds of the Maxville limestone were deposited before this erosion took place, and so shared in it as now to be left in isolated patches, or were deposited at first in limited basins, is as yet undetermined"—the only point concerning the stratum about which he ever had occasion to change his mind, and one which he never determined.

The controversy between Orton and Newberry on the one hand and Andrews on the other led to the publication of the statements of their respective claims during 1878. Orton maintained that one or more beds of coal occur beneath the Maxville, and that the limestone constitutes a zone which can be followed from Vinton County to the Ohio River. Although this was an error, the field evidence was accepted by Newberry. Andrews, on the other hand, again showed the Subcarboniferous age of the Maxville, the Logan age of the subjacent rocks, and that although there were coals below the level of the Maxville, yet none occur underneath it.

The large geologic map of the state was published in 1879, and upon it the Maxville was shown as a continuous belt extending from Dresden to the Ohio River with the exception of a small break at Zanesville. Since this continuity was not in accord with Andrews's view, and since he had no part in the preparation of the map, he objected rather stren-

uously to his name appearing upon it as one of the assistant geologists, and called attention to the fact that the limestone belt crossed the paths of Orton in Pike County, Read in Licking, and Stevenson in Muskingum (northern), but that none of these men saw it.

In 1880 Orton somewhat modified his views in reference to the position to which he assigned the Maxville, and states that the Wellston coal belongs above the limestone, and that he is not sure that the Jackson coal lies below.

A copy of the Annals of the New York Academy of Science appeared in 1882, in which eleven new species of fossils from the Maxville limestone, "the equivalent to the Chester limestone or Chester and St. Louis limestones," were described by Whitfield. Each species was referred to a certain figure and plate in Volume III of the Paleontology of Ohio, but this volume was never printed.

In 1884 Orton unreservedly states that the Maxville "is geologically below both the Wellston and Jackson coals."

Orton refers a limestone that is found in a number of wells in southeastern Ohio to the Maxville, in the 1888 report, and speaks of the variability in composition of the stratum.

During this same year Herrick published a section of the rocks at a point two or three miles west of Fultonham, and admitted his inability to find evidences of an unconformity at any horizon between the Coal Measure rocks and the Waverly. From his study of the fossiliferous blocks in the base of the Sharon in Licking County he concludes that such an unconformity exists there, and that these blocks were derived from the Maxville (Chester) of that vicinity. His conclusions are probably correct, but they cannot be definitely proven since the fossils are so poorly preserved that specific identification is practically impossible.

Since the Ohio report in which the eleven new species of Maxville fossils were to be illustrated was not printed, these forms were illustrated and the descriptions reprinted in the Annals of the New York Academy of Science by Whitfield in 1891. The forms which were already known to science were redescribed and reillustrated, thus raising the total number in the formation to twenty-four species. The descriptions and illustrations of these twenty-four species were reprinted without change in Volume VII of the Ohio Reports, in 1894.

In 1897 Weller stated that the paleontologic evidence points to the equivalence of the Batesville sandstone and the Maxville limestone of Ohio, and in 1902 pronounced the Greenbrier limestone fauna as practically identical with that of the Maxville of Ohio as described by Whitfield.

Bownocker, in 1903, reported the presence of the Maxville limestone in a number of wells in Washington, Monroe, and portions of adjacent counties.

Edward Orton, Jr., and Peppel, in 1904, assigned the Maxville to a position at the base of the Coal Measures, spoke of it as having been

deposited in lakes or ponds of limited area, and gave its most southern exposure as two and one-half miles south of Logan.

In 1906 Orton refers the Maxville to the Sub-carboniferous rather than to the Coal Measures, and again names the same place as its southernmost known deposit. In the same report Orton and Peppel raise the question as to whether the Fultonham stone is not Mercer in age rather than Maxville.

CHAPTER II.

LOCATION AND DESCRIPTION OF EXPOSURES.

The northern extension of the Mississippian limestone outcrops in Ohio at a number of places from the Ohio River near Sciotoville to a point near Zanesville. These outcrops, as has already been stated, are naturally divisible into three areas: a northern area, a central area and a southern area. These areas will now be taken up separately.

THE NORTHERN AREA.

The Northern Area extends from a point just below Logan to a point about a mile beyond White Cottage. It includes parts of Licking, Muskingum, Perry and Hocking counties. Within this field the Maxville has its best development.

JONATHAN CREEK EXPOSURES.

Two of the main branches of Jonathan Creek rise in the southern part of Licking County, and flow south into Perry County. At Glenford they unite, and thence maintain an easterly course through parts of Perry and Muskingum counties to the Muskingum River below Zanesville. The walls of the valley gradually converge to a point one mile east of Mt. Perry where the stream enters a gorge. The gorge consists of intrenched meanders, and continues very narrow as far east as Fultonham (Uniontown). Here a tributary is received from the south and the valley widens abnormally. Beyond, the walls contract and then gradually widen out again.

This lower portion of Jonathan Creek is far within the limits of the Coal Measures, but the stream has cut sufficiently deep in many places to expose the upper part of the Maxville limestone, and in others to show even the whole of the stratum as well as the upper Logan, thus giving us a most beautiful example of an inlier of Maxville—outcrops of Maxville completely surrounded by younger rock. To maintain its course within this gorge from Mt. Perry to Fultonham, it was necessary for the Zanesville & Western Railway to make numerous cuts across the "points" and along the walls of the valley, and many of these cuts show nearly the entire thickness of the Maxville limestone. This series of cuts and the natural exposures make this one of the most important places for the study of the Maxville stratigraphy.

About one mile below Mt. Perry the Zanesville and Western Railway crosses from the south to the north side of Jonathan Creek and follows the north bank until Fultonham is reached. The above crossing is by means of a tall iron bridge, and for convenience it will be called the Mt. Perry Iron Bridge. The cuts will be numbered consecutively down stream from this bridge.

Some two hundred yards below the Mt. Perry Iron Bridge, is Cut No. 1, in which the Sharon member rests upon the uneven surface of the Logan formation. Half-way between the bridge and the cut is a small gully in which the Sharon rests not upon the Logan, but upon the Maxville. For these reasons three sections were made of the cut, one on the south side and two on the north, and one of the gully. These sections will now be given.

Section of the south side of Cut No. 1.

	Ft.	In.	Ft.	In.
A^{10}—Soil	5	0		
Sharon member			13	11
A^{9}—Coarse-grained sandstone to fine conglomerate, friable, yellowish-brown, exceedingly cross-bedded	10	0		
A^{8}—Thin, bluish, argillaceous shales	1	0		
A^{7}—Yellowish-brown, nodular, sandstone layer, containing some iron and fossils	0	4		
A^{6}—Thin, bluish, argillaceous shale	1	0		
A^{5}—Irregular, brownish, coarse-grained sandstone with some iron and plant markings	0	10		
A^{4}—Friable, coarse-grained, shaly sandstone, interbedded with shaly coal	0	9±		
Disconformity.				
Logan formation			18	0
A^{3}—Thin bedded to shaly, bluish to buff sandstone, the upper part soft and yellowish	2	0		
A^{2}—Buff, argillaceous shales with a few thin layers of sandstone	2	3		
A^{1}—Thin bedded to shaly, fine-grained, bluish and buff sandstone to the Zanesville and Western Railway track level	13	9		

Opposite the place where the above section was made, the following complete and partial sections were measured.

Section of the north wall of Cut No. 1.

	Ft.	In.	Ft.	In.
B^{9}—Soil	5	6		
Sharon member			12	4
B^{8}—Coarse-grained sandstone to fine conglomerate, friable, brownish, ferruginous, and exceedingly cross-bedded	11	5		
B^{7}—Soft, coarsely arenaceous, bluish and brownish shale	0	10		
B^{6}—Black, carbonaceous shale. Coal horizon	0	1		

Disconformity.

	Ft.	In.	Ft.	In.
Logan formation			22	4
B^5—Thin-bedded, argillaceous sandstone	0	7		
B^4—Brownish, soft, argillaceous shales with thin sandstone partings	3	6		
B^3—Thin-bedded to shaly, bluish, argillaceous sandstone	2	9		
B^2—Buff, argillaceous shales, with a few thin layers of sandstone	2	3		
B^1—Thin-bedded to shaly, bluish and buff, argillaceous sandstone to the Zanesville & Western Railway track level	13	3		

Five feet down stream from the above section the following partial section of the same wall was made. It includes only the Sharon and soil, and begins at the top of B^3.

Section (B) of the north wall of Cut No. 1.

	Ft.	In.	Ft.	In.
$(B)^7$—Soil	5	6		
Sharon member			16	7
$(B)^6$—Coarse-grained sandstone to fine conglomerate, friable, brownish, ferruginous, and exceedingly cross-bedded	13	5		
$(B)^5$—Argillaceous shale	0	1		
$(B)^4$—Inconstant, nodular layer of brown, ferruginous sandstone	0	4		
$(B)^3$—Friable, coarsely arenaceous, brownish shale	2	3		
$(B)^2$—Bluish-black clay or shale	0	3		
$(B)^1$—Bituminous, shaly coal	0	3		

Disconformity.

Top of B^3

A close comparison of these sections reveals some rather remarkable facts. Beneath the Sharon and above the track in Section B there are twenty-two feet and four inches of Logan, while in Section (B) there are only eighteen feet and three inches, and in Section A only eighteen feet. Although Section (B) is only five feet, and Section A but the width of the cut distant from Section B, the amount of Logan in the (B) and A sections is respectively four feet and one inch and four feet and four inches less than it is in Section B. In all sections the Logan beds are practically horizontal, and the upper line of contact of the formation cuts diagonally across layer after layer of sandstone and shale. Clearly then the Logan was raised above the sea, subjected to erosion, and then submerged some time between its deposition and the deposition of the Sharon. The line of contact between the Logan and

Sharon is, therefore, one of disconformity, or, in other words, an unconformity between parallel beds due to erosion. That this erosion which produced the surface within the Logan, and upon which the Sharon was laid down, was post-Maxville will now be shown.

About one hundred feet from these sections is the up stream end of the cut. Here, across the north wall of the cut, is a ditch in which numerous pieces of hard gray limestone were found. They contain *Productus pileiformis* and belong to the Maxville. From their shape they had evidently been subjected to erosion. Since they lie above the lowest part of the Sharon in the adjacent sections they must have been deposited and then worn away before the Sharon was laid down. Hence the erosion plain upon which the Sharon was deposited was formed in post-Maxville time.

Another important thing is the distribution of the thin zone of coal or carbonaceous matter at the base of the Sharon. This zone is practically continuous, and extends from the bottom of the depressions to the top of the elevations. That the coal could be deposited alike over the minor elevations and depressions shows that the waters of the transgressing sea were at first still and practically free from currents. This tranquillity lasted but for a short period, for the highly cross-bedded sandstone and conglomerate which appear above the coal are the results of swift and changing currents.

Were the few fragments of Maxville limestone which were found in the ditch the only evidence of its deposition and subsequent erosion the statements concerning post-Maxville erosion would be made with more reservation. About one hundred yards up stream from Cut No. 1 and below the Mt. Perry Iron Bridge, however, is a gully in which the Maxville is nicely exposed. For convenience the gully will be called the Bridge Gully, and a section of it will help corroborate the above conclusions.

Section of the Bridge Gully.

	Ft.	In.	Ft.	In.
Sharon member			5	1
C^{19}—Large blocks of micaceous sandstone which are in position farther up.				
C^{18}—Blue, micaceous, arenaceous shale	4	0		
C^{17}—Gray arenaceous shale resembling fire clay	0	8		
C^{16}—Red ferruginous layer with *Productus cestriensis ?*	0	5		
Probable Disconformity.				
Maxville limestone			17	11
C^{15}—More massive limestone, which weathers to a yellowish mass	4	6		
C^{14}—Massive bluish and buff limestone, which weathers to a shale	2	5		

	Ft.	In.	Ft.	In.
C^{13}—Massive layer of rather pure gray limestone *Productus cestriensis* Worthen	5	6		
C^{12}—Layer of pure, compact, gray, fossiliferous limestone. *Derbya crassa* Meek and Worthen..........................	1	9		
C^{11}—Thin nodular layer of bluish limestone alternating with shales. It contains:				
1 Zaphrentis cliffordana Milne-Edwards and Haime				
2. Naticopsis ziczac Whitfield				
3. Productus cestriensis Worthen	2	1		
C^{10}—Layer of bluish-gray pure limestone, containing:				
1. Productus cestriensis Worthen				
2. Seminula subquadrata Hall..	1	1		
C^{9}—Dark or black shale...................	0	2		
C^{8}—Thin bluish limestone	0	1½		
C^{7}—Bluish impure limestone	0	4		
Logan formation............................			29	9
C^{6}—Bluish, argillaceous shale, with calcareous partings, which resemble those of the Waverly. Probably the top of Logan, but it cannot be stated definitely, since the rocks are covered for six feet below	0	8		
C^{5}—Covered, except for a few pieces of fossiliferous limestone, which may be in position	6	0		
C^{4}—Thin-bedded to shaly, argillaceous sand-sandstone.......................	3	0		
C^{3}—Bluish argillaceous shale, with some argillaceous sandstone layers	2	2		
C^{2}—Slightly covered. Mostly thin-bedded to shaly, bluish argillaceous sandstone..	11	2		
C^{1}—Covered to the Zanesville and Western Railway track level, nine rail lengths (270 feet) from the previous sections	6	9		

The top of the Logan in the section just given is at least twenty-three feet and one inch and probably twenty-nine feet and nine inches above the track level. In either case it raises the base of the Maxville limestone above the base of the Sharon in Cut No. 1. It was impossible for the Maxville to have been deposited in higher places (i. e., in the gully and ditch where now found) without being deposited at the same time in the adjacent lower places (i. e., in Cut No. 1). The Maxville must, therefore, have been a continuous deposit, and it, with a part of the Logan, must have been subsequently removed from these basins in which the Sharon now rests upon the Logan.

Since the red ferruginous layer, C^{16}, in the Bridge Gully contains a fossil which is probably *Productus cestriensis* there is a strong in-

clination to refer the layer to the Maxville. Careful study at other and better exposures shows, however, that it is a continuous deposit very similar in its relations and distribution to the thin coal of the first section. It is, therefore, made the basal interval of the Sharon in this section.

The limestone in this region dips to the east or to the south of east. The rate of dip, while not perceptible, is even greater than the gradient of the stream. This brings the base of the Maxville nearer and nearer track and stream level as we progress in our study of the series of cuts. By the time Fultonham is reached the lower half of the limestone has passed beneath drainage. And, finally, at a point about two miles below White Cottage the whole disappears below the waters of Jonathan Creek.

About one-fourth of a mile below Cut No. 1 the railroad was compelled to cross another "point." This gives us Cut No. 2, in which quite an interval of the Maxville is exposed.

Section of the north wall of Cut No. 2.

	Ft.	In.	Ft.	In.
Maxville limestone			8	8
D9—Top of exposure in ditch above cut. Poorly exposed, but apparently more massive, bluish-gray limestone without shaly partings	3	4		
D8—Irregular and wavy-bedded, bluish, compact limestone in medium layers, which alternate with wavy shale intervals. Contains: 1. Dielasma turgida Hall	3	2		
D7—Nodular, bluish, fossiliferous limestone	2	2		
Undetermined zone			2	4
D6—Covered interval. It is not known whether this belongs to the Maxville or to the Logan				
Logan formation			18	8
D5—Layer of blue, argillaceous sandstone, which, on weathering, breaks up into thin layers	0	9		
D4—Blue argillaceous shales with an occasional sandstone parting	3	9		
D3—Thin-bedded, blue argillaceous sandstones alternating with shales	2	3		
D2—Blue argillaceous shales	1	8		
D1—Thin to massive-bedded blue argillaceous sandstone, some of which are slightly cross-bedded To track level	10	3		

Below Cut No. 2, in turn, is Cut No. 3, and in this cut the Maxville is beautifully shown.

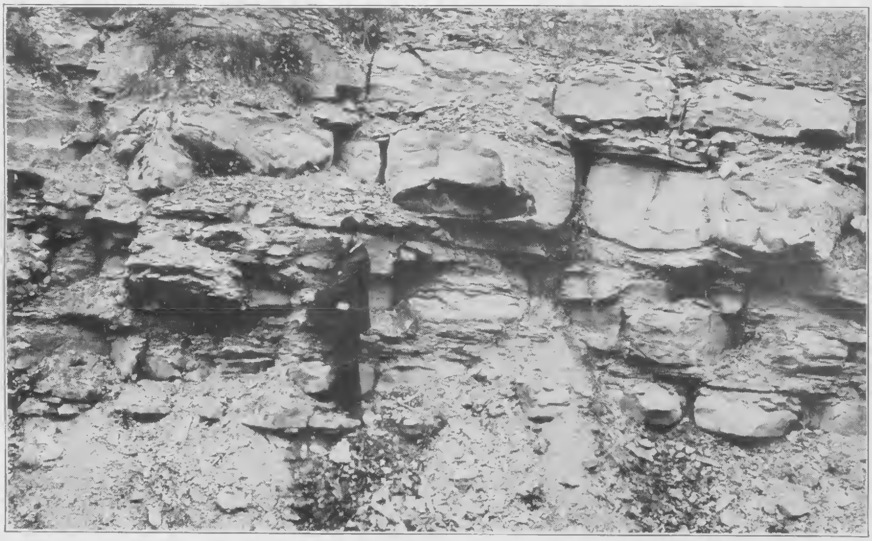
Section of Cut No. 3.

	Ft.	In.	Ft.	In.
E^{14}—Top of cut. Soil	3	0		
Sharon member			5	3
E^{13}—Shales and talus	5	0		
E^{12}—Iron ore, the position of which is not clear	0	3		
Maxville limestone			13	4
E^{11}—Clay. About five feet away, however, is a five-inch block of limestone with iron ore clinging to its upper surface. The block occupies this horizon, but since it is slightly tilted, the top of the Maxville is not quite certain	0	5		
E^{10}—Massive bluish to pinkish limestone. Contains *Productus cestriensis* Worthen	4	0		
E^{9}—Massive layer of bluish to pinkish fossiliferous limestone	1	8		
E^{8}—Massive layer of blue and pink fossiliferous limestone	2	0		
E^{7}—Medium bedded to shaly limestone, which is argillaceous and varies in color from a pink to a buff. The fossils collected are: 1. Zaphrentis cliffordana Milne-Edwards and Haime 2. Productus cestriensis Worthen 3. Dielasma turgida Hall 4. Seminula subquadrata Hall	3	6		
E^{6}—Shaly, argillaceous, non-fossiliferous limestone. It probably consists of worked over sand and clay which were in turn mixed with calcareous material, and is probably also the base of the Maxville	1	9		
Logan formation			12	1
E^{5}—Bluish, impure limestone with a velvet-like luster, resembling calcareous layers of the Waverly farther south	1	4		
E^{4}—Buff, argillaceous shale	2	6		
E^{3}—Thin-bedded to shaly, argillaceous sandstone	2	9		
E^{2}—Buff, argillaceous shales, with thin, argillaceous sandstone partings	2	0		
E^{1}—Massive, buff, argillaceous sandstone, which is slightly cross-bedded and which breaks up into thin layers. To track level	3	6		

On account of the dip only one more cut shows the contact between the Logan and Maxville. This is Cut No. 4, which is located a fraction of a mile below the last one.

Section of Cut No. 4.

	Ft.	In.	Ft.	In.
F^8—Soil and talus from the Sharon. The top of the Maxville is not exposed......	11	0		
Maxville limestone..........................			15	7
F^7—Rather massive layer of limestone, the upper part of which has broken up into shale and all of which has weathered to a brownish buff. Among other fossils it contains: 1. Productus cestriensis Worthen	5	6		
F^6—Nodular layers of gray, compact limestone with thin shaly partings. The limestone shows the stylolites structure. It contains: 1. Productus pileiformis McChesney 2. Productus cestriensis Worthen 3. Spirifer keokuk Hall 4. Cypricardella oblonga Hall 5. Dentalium illinoiense Worthen 6. Bulimorpha canaliculata Hall 7. Bellerophon sublævis Hall 8. Strophostylus carleyana Hall 9. Murchisona vermicula Hall 10. Nautilus pauper ? Whitfield..	0	11		
F^5—Layer of bluish-gray limestone somewhat purer than that below. The fossils are: 1. Productus cestriensis Worthen 2. Spirifer sp. 3. Pelecypod shells	2	9		
F^4—Blue limestone without apparent bedding planes, but which becomes shaly, buff and arenaceous-like on weathering. The fossils are: 1. Zaphrentis sp. 2. Productus cestriensis Worthen 3. Seminula subquadrata Hall 4. Allorisma maxvillensis Whitfield 5. Bellerophon sublævis ? Hall..	6	0		
F^3—Soft, bluish, argillaceous shale, which probably belongs to the base of the Maxville	0	5		
Logan formation............................			4	11
F^2—Layer of blue limestone with a velvet-like luster. It breaks up into pieces, and resembles similar layers of the Waverly	0	7		
F^1—Blue, argillaceous, shaly sandstone. with thicker partings and with an inconstant, nodular, calcareous layer near the top. To track level	4	4		



A.—A view of the Maxville limestone in Cut No. 4 between Mt. Perry and Fultonham, showing the impure lower portion and the basal contact on which Prof. Prosser stands.

B.—An exposure of the Maxville limestone in Jonathan Creek opposite the Fultonham Depot, showing the conspicuous stratification of the upper half, due in part to solution along the bedding planes and in part to the removal of the shaly partings.

In the early study of this exposure (Cut No. 4) a collection of fossils was made from the stratum as a whole, and includes the following:

1. Bryozoan impression
2. Productus cestriensis Worthen
3. Spirifer keokuk Hall
4. Dielasma turgida ? Hall
5. Seminula subquadrata Hall
6. Bellerophon sublævis Hall
7. Orthonychia acutirostre Hall

Special attention should be called to

1. Cypricardella oblonga Hall
2. Dentalium illinoiense Worthen
3. Bulimorpha canaliculata Hall
4. Strophostylus carleyana Hall
5. Murchisona vermicula Hall
6. Orthonychia acutirostre Hall

which are new to the Maxville limestone. With the exception of *Dentalium illinoiense* this is a portion of the Spergen Hill (Salem limestone) fauna, which consists of a large number of mostly diminutive species of Gasteropoda, Pelecypoda and Brachiopoda and which reappears again in the Ste. Genevieve limestone and again in the Tribune limestone. Portions of these small Gasteropods, especially *Murchisona vermicula,* are very abundant in zone F^6 of this exposure.

Specimens of *Productus cestriensis* Worthen are frequently slightly crushed. Nevertheless they are robust forms, and, in this latter respect, they resemble specimens of the same species found in the lower half of the stratum farther to the south.

By referring to the last two sections, E and F of Cuts No. 3 and No. 4, it will be seen that the rocks at the top of the Logan rather blend into those at the base of the Maxville. The line of contact is not lithologically distinct and neither were there any fossils found in the limiting interval. It must be admitted then that the line of contact has been somewhat arbitrarily drawn. Since the Maxville is a limestone and the Logan a sandstone there is a strong temptation to extend the lower limits of the Maxville down one interval, in each section, and include the blue, impure limestone with a velvet-like luster. Examination of a large number of sections farther south has shown, however, that there is frequently to be found in the upper part of the Waverly one or more layers of blue, impure limestone with the same velvet-like luster. For this reason the impure limestone interval has been referred to the Logan.

The clayey and sandy nature of the lower five or six feet of the Maxville limestone is very interesting. As understood today this is taken to indicate a combination of environments. It suggests a com-

mingling of fairly deep and quiet sea conditions on the one hand and littoral or slightly off-shore on the other. To have such conditions presupposes a shore line migrating either landward or seaward.

Which of these movements we had in the case of the Maxville does not seem difficult to determine. Commencing at the base the Maxville becomes successively purer and purer as we ascend. This shows that the sea must have grown deeper and deeper and more and more quiet. Successively deeper and more quiet water is the product of a transgressing sea, of which the Maxville sea was a representative. The Maxville limestone and the Logan formation must, therefore, be considered as an illustration of transgressive overlap, as defined by Grabau ([1]).

From the few, only two or three, poor exposures of the Logan-Maxville contact already described, it is not possible to determine positively that the Maxville rests disconformably upon the Logan, although it will be shown to do so in the exposures to the south. But when all the phases of the subject are considered, it seems more than probable that the Logan was deposited beneath the sea, then raised to a land surface and subjected to the agents of weathering and erosion, before the deposition of the Maxville. As the Logan was over-ridden by the transgressing Maxville sea the unconsolidated residual sediments forming the top of the Logan were slightly worked over and mixed with the calcareous material forming the base of the Maxville.

Thus far it has been impossible to correlate any layer in a section with the same layer in another section. The sequence of deposition of the lower part of the Maxville seems to have been slightly different for each of the sections studied. Correlation is possible, however, in the sections which follow, at least those in this part of the Northern Area.

Section of Cut No. 5.

	Ft.	In.	Ft.	In.
Sharon member			13	3
G^{13}—Medium-bedded, coarse-grained sandstone	4	9		
G^{12}—Irregular, shaly to thin-bedded, coarse-grained sandstone	3	0		
G^{11}—Black, arenaceous and carbonaceous shales, with iron ore nodules	5	0		
G^{10}—Iron ore	0	4		
G^{9}—Gray shale	0	2		
Disconformity.				
Maxville limestone			23	7
G^{8}—Layer of dark bluish-gray limestone. Contains many Gasterpods at the top	1	6		

[1]Grabau, Amadeus W. Types of Sedimentary Overlap. *Bull. Geol. Soc. Am.*, Vol. XVII, pp. 570, 571.

	Ft.	In.	Ft.	In.
G^7—Shale-nodular zone. Nodular-like layers of limestone, alternating with shales. Both are very fossiliferous, containing: 1. Productus cestriensis Worthen 2. Dielasma turgida Hall 3. Seminula subquadrata Hall 4. Allorisma maxvillensis Whitfield 5. Straporollus similis Meek and Worthen 6. Bulimorpha melanoides Whitfield 7 Naticopsis ziczac Whitfield. 8. Bellerophon sublævis Hall...	3	3		
G^6—Reddish, argillaceous shales, with an occasional limestone parting.........	1	6		
G^5—Layer of bluish-gray compact limestone	0	4		
G^4—Massive layer of bluish, fossiliferous limestone, which weathers to a yellowish buff. On exposure the upper foot or foot and a half breaks into layers	8	4		
G^3—Massive layer of bluish limestone with an uneven base. The color changes to a buff when subjected to the elements. The fossils collected are: 1. Productus cestriensis Worthen 2. Spirifer sp.	4	10		
G^2—Nodular layers of bluish, compact limestone, with thin, shaly partings. Stylolites structure developed. Probably the equivalent of F^6. Contains: 1. Productus cestriensis Worthen 2. Bellerophon sublævis Hall 3. Gasteropod shells, small.....	0	10		
G^1—Massive layer of bluish limestone which weathers to a buff color. The fossils are: 1. Productus cestriensis Worthen 2. Dielasma turgida Hall. To one and one-half feet below track level	3	0		

The nodular layers with thin shale partings which make up G^2 in Cut No. 5, are quite probably the equivalents of those of F^6 in Cut No. 4. In Cut No. 5 the equivalents of F^3 and F^4, then, would lie below track level. In other words, six feet and five inches of the base of the Maxville are covered beneath the lowest exposed layer, G^1, in Cut No. 5. If these two basal intervals be present in Cut No. 5, the total thickness of the Maxville, at this place, will then reach thirty feet, while the mas-

sive "lower zone" lying below the "shale nodular zone," G^7, will have a thickness of twenty-five feet and three inches.

Section of the upper end of Cut No. 6.

	Ft.	In.	Ft.	In.
Sharon member			11	6
H^8—Dark, arenaceous shales	11	0		
H^7—Iron ore	0	4		
H^6—In part. The upper one or two inches of this layer contain much iron, but it is firmly cemented to the remainder of the layer	0	2		
Disconformity.				
Maxville limestone			15	9
H^5—In part. Massive layer of bluish-gray fossiliferous limestone. It contains some rather small Gasteropod shells	1	1		
H^4—Three to four medium and slightly wavy layers of fossiliferous limestone with thin partings of shale	1	10		
H^3—Massive layer of dark, reddish-gray limestone. Gasteropods abundant	1	7		
H^2—Shale-nodular zone. Nodular-like layers of bluish limestone alternating with blue shale. The lowest layer of limestone is the thickest. Both the shales and the limestones are very fossiliferous, and are the equivalent of those grouped under G^7 in the last section. Among other fossils are: 1. Productus cestriensis Worthen 2. Seminula subquadrata Hall 3. Allorisma maxvillensis Whitfield 4. Naticopsis ziczac Whitfield 5. Bellerophon sublævis Hall	3	6		
H^1—Covered to track level	7	9		

That the nodular-like layers of bluish limestone which alternate with blue shales in G^7 (Cut No. 5) and H^2 (Cut No. 6) make up one and the same zone there seems to be no question. Both limestone and shale are exceedingly fossiliferous; far more so than any other horizon in the Maxville. *Productus cestriensis, Seminula subquadrata* and *Straparollus similis* literally fill the mass in places. The shales easily disintegrate, leaving the fossils free. After a rather large area of shales has been exposed for some time the fossils can actually be scooped up with a shovel. This fossiliferous zone is very striking when it is recalled that much of the Maxville is very sparingly fossiliferous, and in places practically barren.

A view of the Maxville limestone and the Sharon member in Cut No. 5, between Mt. Perry and Fultonham, showing most of the massive lower zone extending to the feet, the shale-nodular zone reaching to the hammer, and the upper zone here consisting of but one layer.

Since reference will be made repeatedly to the above zone, G^7 and H^2, it will be called the *shale-nodular zone* for convenience. That portion below this zone will be called the *lower zone.* That above will be designated the *upper zone.*

Attention has already been called to the iron ore superimposed upon the limestone. Because of its importance, however, it will be necessary to refer to it a number of times. Frequently at least a part of the ore seems to form a part of the uppermost layer of limestone, and was, accordingly, at first included in the Maxville. Further study showed, however, that where the Maxville was eroded to a shale zone the ore is a distinct layer in itself, but when the erosion stopped on a limestone layer the ore is more or less cemented to the weathered surface of the limestone. In many places the erosion of the Maxville was succeeded by a deposition of the iron ore and the ore is, therefore, placed in the Pennsylvanian series.

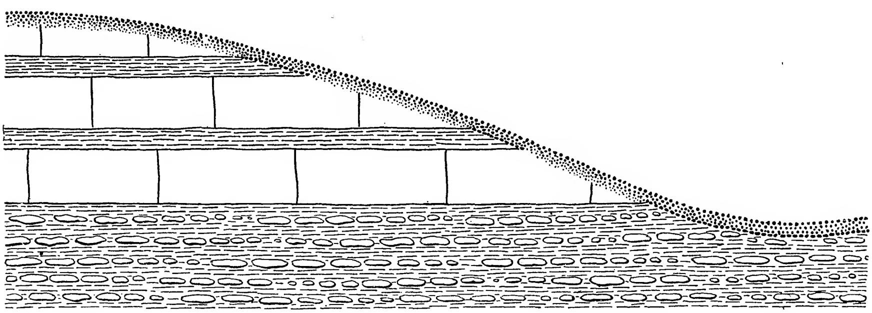


Fig 1.—A diagram of the uneven upper surface of the Maxville limestone and the iron ore in the base of the Pennsylvanian. Where the ore rests upon a layer of limestone it seemingly forms the top of the Maxville, but where it rests upon a zone of shale it clearly constitutes a distinct layer.

When the Section (G) of Cut No. 5 is compared with the Section (H) of the upper end of Cut No. 6 it will be seen that the Maxville has suffered more from erosion in the former than it has in the latter. The upper end of Cut No. 6 has two more intervals, H^4 and H^5, of limestone above the shale-nodular zone than has Cut No. 5. The denuding agents therefore penetrated three feet deeper in the vicinity of Cut No. 5 than they did at the upper end of Cut No. 6.

A nearer and therefore more striking example of unequal erosion is seen by passing down stream three rail lengths (90 feet) from where Section H was measured in the upper end of Cut No. 6. At this point the nineteen-inch layer designated H^3 has been reduced to eight inches in thickness. All of the superjacent layers have been swept away and the iron ore rests directly upon the layer which has been reduced to eight inches.

By carefully tracing the upper layer down stream in this, the upper end of Cut No. 6, it can actually be seen to be worn thinner and thinner until it finally disappears. The next lower layer can also be traced until it also finally disappears in a like manner, and so with other succeeding layers. Better proofs of unconformity, due to erosion, between the Maxville and the superjacent Pennsylvanian strata could not be desired and to the writer they are conclusive.

A short distance down stream from the last section and still within the same cut the following section was made:

Section of the middle of Cut No. 6.

	Ft.	In.	Ft.	In.
Sharon member			20	6
I^7—Black, soft, carbonaceous shale	1	0		
I^6—Dark gray, arenaceous shale	18	6		
I^5—Ferruginous shales and red iron ore	1	0		
Disconformity.				
Maxville limestone			11	0
I^4—Shale-nodular zone. Nodular-like layers of blue, compact limestone alternating with shales. The lowest layer is the thickest. Both limestones and shales are very fossiliferous. Among other fossils are: 1. Productus cestriensis Worthen 2. Seminula subquadrata Hall	1	7		
I^3—Reddish, argillaceous shales with two rather thick layers, one of which is blue and calcareous and the other red and ferruginous	2	7		
I^2—Bluish-gray, compact limestone, which is sparingly fossiliferous	0	10		
I^1—Massive layer of light colored limestone, the whole of which weathers to a buff and the upper part to thin layers. To one foot below track level	6	0		

Before this section was carefully studied and measured a collection of fossils was made from loose material in the face of the cut. It is probable that the majority, if not all of the specimens, came from the shale-nodular zone (I^4). The collection contains:

1. Productus cestriensis Worthen
2. Dielasma turgida Hall
3. Seminula subquadrata Hall
4. Allorisma andrewsi Whitfield
5. Allorisma maxvillensis Whitfield
6. Straparollus similis Meek and Worthen

7. Bulimorpha melanoides Whitfield
8. Sphærodoma subcorpulenta Whitfield
9. Naticopsis ziczac Whitfield
10. Bellerophon sublævis Hall
11. Trilobite unidentified.

This section, I, of the middle of Cut No. 6, is only twelve rail lengths (360 feet) down stream from the preceding section, H, of the upper end of Cut No. 6. The Maxville has suffered six feet and five inches more erosion here than at the preceding place. When the last three sections (G, H and I) are compared, the line of disconformity is seen to be low in the Maxville scale in Cut No. 5, somewhat higher in the upper end, and low again in the middle of Cut No. 6.

Just below Cut No. 6 a public highway crosses the Zanesville and Western Railway tracks and in turn Jonathan Creek by means of a high iron bridge. This bridge is known as the Wortman Bridge. Between it and the Mt. Perry Iron Bridge are to be found all of the sections so far described.

Between the Wortman Bridge and Fultonham not only are the railroad cuts insignificant or wanting, but the top of the Maxville has almost passed below track level. Study of the Maxville has to be confined almost exclusively, therefore, to the banks of the stream. About halfway between the above points and about opposite Trestle No. 41 is Hough Hollow. It is on the opposite side of Jonathan Creek from the one on which the railroad is located. Along the banks of the main stream and up the branch, the Maxville is nicely exposed, and above it the Pottsville formation. The following section, taken at this point, shows the strata only a short distance above the Maxville.

Section of the south bank of Jonathan Creek at the mouth of Hough Hollow.

	Ft.	In.	Ft.	In.
Sharon member			4	6
J^{13}—Irregular-bedded, dark, arenaceous shales and coarse sandstone	4	0		
J^{12}—Iron ore	0	6		
Maxville limestone			17	5
J^{11}—Mostly covered, except a few inches of limestone at the top, and these are exposed farther up the run	1	7		
J^{10}—Layer of bluish-gray, fossiliferous limestone	1	6		
J^{9}—Layer of limestone with a pinkish tinge	2	2		
J^{8}—Weathered space, probably formerly occupied by shales	0	3		
J^{7}—Layer of limestone of pinkish hue	1			
J^{6}—Layers of irregular-bedded pink limestone	2	2		

	Ft.	In.	Ft.	In.
J^5—Layer of dark bluish-gray, compact limestone	1	10		
J^4—Shale-nodular zone. Nodular-like layers of blue, compact limestone alternating with blue shale. The lowest layer of limestone is the thickest. Both limestone and shales are very fossiliferous. The following were noted: 1. Productus cestriensis Worthen 2. Dielasma turgida Hall 3. Seminula subquadrata Hall 4. Straparollus similis Meek and Worthen 5. Bellerophon sublævis Hall ..	2	9		
J^3—Pink argillaceous shales with two or three calcareous partings. The interval is slightly covered	1	5		
J^2—Bluish, compact, pure limestone	0	9		
J^1—Covered, except for two or three inches of limestone at the top. To low water level in Jonathan Creek	1	6		

The point has now been reached where, by combining parts of several sections, the complete thickness of the Maxville can be, at least approximately, determined. By taking portions of the sections of Cuts No. 4 and No. 5 we have, already, obtained twenty-five feet and three inches as a thickness for the lower zone of the formation. If to this be added that portion of the section of Hough Hollow forming the shale-nodular zone (J^4) of two feet and nine inches, and the upper zone (J^5-J^{11}), of eleven feet, a total thickness of thirty-nine feet for the formation is the result.

Enough sections have now been given to justify some generalizations in regard to the character of the lower and upper zones of the limestone. If sections F to J of Cuts No. 4 to No. 6 and of Hough Hollow be carefully studied, the lower zone will be seen to be practically made up of massive layers of limestone. The bedding planes are not conspicuous, the stone weathers to a buff, and the bottom layers are clayey. The layers of the upper zone are, on the other hand, thin to medium-bedded. In the face of a cliff the stratification is the conspicuous feature. Solution along the bedding plane or removal of the thin partings of shale causes each layer to project independently. The layers are purer limestone than those belonging to the lower zone, and their color is usually a blue or bluish-gray rather than a buff. In other words, the lower and upper zones are very dissimilar and in this region should not be confused.

In some places, the upper part is covered or has been removed by

pre-Pottsville erosion, leaving only the lower part exposed. In other places, the upper part only is exposed, while in still others, parts of both halves are revealed. The dissimilarity of the two halves of the formation has just been discussed. When one part of the limestone at one place is compared with another part at another you should not, therefore, expect them to be similar, and yet it is this comparison of dissimilar parts that has caused some of the later writers to say that the Maxville shows wide differences in composition and stratification in short distances.

In the Hough Hollow exposure, the shale-nodular zone was three feet and eight inches above water level. At the upper end of Fultonham are the Zanesville and Western Railway coal chutes, where their locomotives are "coaled," and on the opposite bank from the chutes the base of the shale-nodular zone is at low water mark. Down stream, before the next exposure is reached, the zone has dipped below water level. Just below Fultonham, Buckeye Fork enters Jonathan Creek from the south. About one-eighth of a mile below the confluence and on the opposite side of the stream is quite an exposure of Maxville. The shale-nodular zone has remained beneath drainage to this point, but here a small anticline or deeper erosion brings it up to low water mark. If we continue down stream from here to White Cottage the shale-nodular zone is not found above water level again. Going up Kents Run about one mile from White Cottage, however, a covered wooden bridge is reached where the zone again rises to water level.

At the coal chutes, quite an area of the layer designated J^5, the first one above the shale-nodular zone, is exposed. It is rather abundantly and conspicuously jointed. So also is the layer that forms the bed of the creek opposite the Fultonham depot, and the two are probably one and the same layer. At the latter place there are thirteen feet of limestone exposed. If the bottom layer be correctly identified, then one foot and ten inches added for its (J^5) thickness, would give fourteen feet and ten inches for the upper zone. If to this measurement be added two feet nine inches and twenty-five feet three inches, respectively, for the supposed shale-nodular zone and lower zone, a total thickness of forty-two feet ten inches for the Maxville is obtained. This thickness agrees very closely with the forty-five feet found by the Fultonham Brick Company in their drill holes.[1]

The Zanesville and Western Railway crosses from the north to the south side of Jonathan Creek at the upper end of Fultonham. It maintains its course on the south side of the creek until a point beyond White Cottage is reached. Immediately below Fultonham it crosses

[1]Orton, Jr., Edward. The Composition of the Limestones of Ohio. *Geol. Surv. Ohio,* Bull. 4, p. 105.

Buckeye Fork, just before this stream empties into Jonathan Creek, by means of a low iron bridge.

From a point about one hundred yards above the upper bridge to a point a like distance below the lower bridge, the Maxville limestone makes up the floor and walls of the channel. The shale-nodular zone was seen to pass below water level just above the upper limit and remain beneath until just below the lower limit. The limestone exposed within this stretch, therefore, belongs to the upper half of the formation. It is a gray, compact stone made up of conspicuous medium layers. This latter feature is nicely shown in the following section which was taken just below the mouth of Buckeye Fork where Jonathan Creek has excavated a rather deep channel.

Section of the south bank of Jonathan Creek at the mouth of Buckeye Fork.

	Ft.	In.	Ft.	In.
Soil				
Maxville limestone			13	9
K7—Thin-bedded, gray, compact, fossiliferous limestone. Contains: 1. Pentremites sp	6	6		
K6—Layer of gray, compact, fossiliferous limestone. Contains, besides numerous specimens of small Brachiopods: 1. Zaphrentis cliffordana ? Milne-Edwards and Haine 2. Pentremites elegans Lyon	1	9		
K5—Layer of bluish-gray, compact limestone. Among other fossils are: 1. Martinia contracta Meek and Worthen (a) 2. Spirifer rockymontanus ? Marcou 3. Corals	1	8		
K4—Layer of bluish-gray, compact limestone. Contains, among other fossils: 1. Derbya crassa Meek and Worthen	1	3		
K3—Layer of gray, compact, fossiliferous limestone	1	2		
K2—Parting of soft shale	0	2		
K1—Gray, compact, fossiliferous limestone layer, which forms a half of the bed of the stream. To water level	1	3		

A general collection from this place and from another exposure of the same zone still farther down stream, includes the following additional forms:

1. Cyathocrinus maxvillensis Whitfield
2. Asterozoan unidentified

3. Bryozoan unidentified
4. Productus pileiformis McChesney
5. Straparollus similis Meek and Worthen
6. Nautilus pauper ? Whitfield

The shale-nodular zone rises above water just down stream from this place, and therefore the lowest interval of this section probably extends almost to this zone. How near the highest interval is to the top of the formation is not known since there is a soil covering. By passing up Buckeye Fork for a short distance, however, the top of the limestone is reached, and the formation then forms the floor of the channel for about a half mile farther.

At the point, one-eighth of a mile below the confluence of Buckeye Fork and Jonathan Creek, where the shale-nodular zone is exposed, the upper zone of the Maxville reaches a thickness of twenty-one feet and six inches. This is the greatest thickness yet found for this division of the limestone. The shale-nodular zone is present. Granting that the lower half is present also and that both have the usual thickness of two feet nine inches and twenty-five feet three inches, respectively, the total thickness of the Maxville reaches forty-nine feet six inches. Since the section at this point was measured in detail, it brings out the stratification even more markedly than did the last section. Therefore it will be given.

Section of the north bank of Jonathan Creek one-eighth of a mile below the mouth of Buckeye Fork.

	Ft.	In.	Ft.	In.
Soil				
Maxville limestone			22	8
L^{23}—Thin-bedded, gray, fossiliferous limestone to top of exposure in a ditch	1	10		
L^{22}—Interval practically all covered	1	9		
L^{21}—Thin-bedded, gray, fossiliferous limestone	2	7		
L^{20}—Layer of compact, gray limestone, forming the top of bank	0	9		
L^{19}—Parting	0	4		
L^{18}—Layer of compact gray limestone	0	10		
L^{17}—Two layers of compact gray limestone with shaly and nodular partings	1	3		
L^{16}—Layer of compact gray limestone which may separate into two	1	6		
L^{15}—Two thin layers of gray limestone with thin partings	0	9		
L^{14}—Layer of compact gray limestone	0	7		
L^{13}—Shaly parting	0	1		
L^{12}—Layer of compact, gray, fossiliferous limestone which may break into several layers. Contains: Bellerophon sublævis Hall	1	2		

	Ft.	In.	Ft.	In.
L^{11}—Shaly parting	0	1		
L^{10}—Layer of compact gray limestone	0	11		
L^{9}—Shaly parting	0	1		
L^{8}—Layer of compact gray limestone	1	3		
L^{7}—Shaly parting, wavy	0	5		
L^{6}—Layer of compact gray limestone	1	5		
L^{5}—Shaly zone, frequently with a layer of nodules at the center	0	6		
L^{4}—Layer of compact gray limestone	0	6		
L^{3}—Shaly parting, wavy	0	1		
L^{2}—Thick layer of compact gray limestone, which contains some calcite and some fossils. The upper surface often breaks up into one or two extra layers	2	10		
L^{1}—Shale-nodular zone. Nodular layers alternating with shale, to low water level	1	2		

Between the last exposure and White Cottage the Maxville limestone is shown at only one or two places. Somewhat below the last exposure and on the opposite side of the stream is one of these, and some ten or fifteen feet are exposed. These belong to the upper part of the formation, and the disappearance of the shaly intervals allows the medium layers to project in the usual manner.

By the time White Cottage is reached the dip and pre-Pottsville erosion have been sufficient to bring the top of the stratum to almost water level. From the dam at the old Gladstone Mill to a point below the depot, these few upper feet of limestone form the bed of the stream. The upper contact is shown directly under the mill where the following section was measured:

Section at Gladstone Mill.

	Ft.	In.	Ft.	In.
Pottsville formation			0	11
M^{6}—Layer of micaceous, coarse-grained, brownish, iron-stained sandstone to the top of the exposure under the mill. Across the stream and above the Zanesville and Western Railway a number of feet of Pottsville shales are exposed	0	5		
M^{5}—Black, bituminous shale	0	4		
M^{4}—Iron ore, mostly adhering to the top of the limestone	0	2		
Maxville limestone			5	8
M^{3}—Four rather irregular and thin layers of limestone with thin shaly partings which weather out, leaving the layers projecting. Besides numerous small				

	Ft.	In.	Ft.	In.
Crinoid stems, it contains the following fossils: 1. Productus cestriensis Worthen 2. Martinia contracta Meek and Worthen 3. Spirifer rockymontanus Marcou 4. Derbya crassa ? Meek and Worthen 5. Bulimorpha melanoides ? Whitfield	1	2		
M^2—Compact, pure gray limestone which separates into thin layers. Solution may take place along the bedding planes. Fossiliferous	3	3		
M^1—Layer of compact gray limestone, the upper three inches often separating into an extra layer. Base extending below water level	1	3		

A number of fossils were collected from a large, flat block of limestone at the mill. Although the block was loose it undoubtedly came from the upper five or six feet of the stratum as exposed at this place. The specimens came from a three-inch zone and include:

1. Zaphrentis cliffordana Milne-Edwards and Haime
2. Pentremites sp.
3. Dielasma turgida Hall
4. Spirifer rockymontanus Marcou
5. Seminula subquadrata Hall
6. Martinia contracta Meek and Worthen
7. Straparollus similis Meek and Worthen

A general collection from the upper five or six feet of the limestone as exposed between Gladstone Mill and the White Cottage Depot gave the following additional forms:

1. Productus pileiformis McChesney
2. Allorisma andrewsi Whitfield
3. Bellerophon sublævis Hall
4. Trilobite unidentified

In the fourth or fifth layer of limestone above the shale-nodular zone at Fultonham, *Martinia contracta* is rather abundant. At White Cottage this same Brachiopod is rather common. These are the only places known where this fossil occurs in considerable numbers.

KENTS RUN EXPOSURES.

At White Cottage Jonathan Creek receives the waters of Kents Run from the north. This stream rises in Muskingum County near the National Road, flows north, thence west, thence south across the road, and finally to the southeast. In the lower half of its course it is about parallel

with Jonathan Creek. The upper half of its course is through glaciated country and the valley is rather open. The lower half, on the other hand, flows through a non-glaciated region and the valley becomes a gorge over two hundred feet deep and surpasses that of Jonathan Creek. Before the coming of the Rural Free Delivery and the passing of the cross-roads postoffice, Opera Postoffice was located at the head of the gorge.

As the Maxville limestone is exposed, as an inlier, more or less of the way along Jonathan Creek from Mt. Perry Iron Bridge to White Cottage, so also is the stratum exposed along Kents Run from Opera to the same place. Corresponding exposures are also very similar in the two streams. Starting at Opera with only the lower zone, and this above drainage, the formation approaches nearer and nearer stream level and finally passes below the run before White Cottage is reached. The upper zone has also been removed until a covered bridge one mile above White Cottage is reached. From this point to White Cottage the upper zone of the stratum is above drainage. Above Opera the limestone is poorly exposed at intervals for at least a mile.

At Opera a covered bridge crosses Kents Run, and just below the bridge is a series of good exposures. A few sections of these will now be given in order to show the Maxville-Pottsville disconformity and the consequent variation in thickness of the limestone stratum.

Section of the west bank of Kents Run, one hundred yards below Opera Bridge.

	Ft.	In.	Ft.	In.
Soil				
Maxville limestone			5	6
A8—Thick layer of buff argillaceous limestone	2	5		
A7—Thin layer of limestone, usually with a shaly parting above and below	0	4 ±		
A6—Layer of grayish or buff argillaceous limestone. Twelve feet downstream this layer was worn down to 10 inches, and three feet farther the whole of the limestone stratum was worn away, but reappears again	1	10		
A5—Irregular, shaly parting. In places this becomes indurated, when the layer above and the one below are united	0	2 ±		
A4—Irregular layer of buff or gray argillaceous limestone	0	9		
Logan formation			2	4
A3—Black bituminous shale. The contact with the limestone above is slightly wavy	0	1		
A2—Blue shaly sandstone	0	3		
A1—Soft, argillaceous blue shale to water level	2	0		

Section twelve feet down stream from the last.

	Ft.	In.	Ft.	In.
Pottsville formation			5	3
B8—Cross-bedded, coarse-grained brown sandstone to the top of the exposure	5	0		
B7—Iron ore	0	3		
Disconformity.				
Maxville limestone			1	9
B6—Layer of argillaceous buff limestone, the upper surface of which was eroded one foot in less than twelve feet	0	10		
B5—Shaly parting	0	2 ±		
B4—Irregular layer of argillaceous buff limestone	0	9		
Logan formation			1	11
B3—Black bituminous shale. Contact with the limestone above slightly wavy	0	1		
B2—Blue shaly sandstone	0	3		
B1—Soft, argillaceous blue shale to water level at the same place	1	7		

These two sections reveal a beautiful example of disconformity. They show a difference of pre-Pottsville erosion in the upper surface of the Maxville limestone of at least three feet nine inches in a horizontal distance of twelve feet. The top layer of limestone (A8) can actually be traced until it completely disappears, as can also the next lower interval (A7). The third layer (A6) of one foot ten inches is seen to diminish to a thickness of only ten inches in this same distance.

About three feet farther down stream the whole of the formation was probably worn away. This is true of the layers of limestone. But since the Sharon sandstone does not quite reach the dark shale, A3 and B3, of the Logan, but rests upon a few inches of shale or clay, it is not quite clear whether this clay or shale belongs to the Sharon or not. It seems more than probable, however, that it does.

A few feet farther down stream the limestone layers appear again,

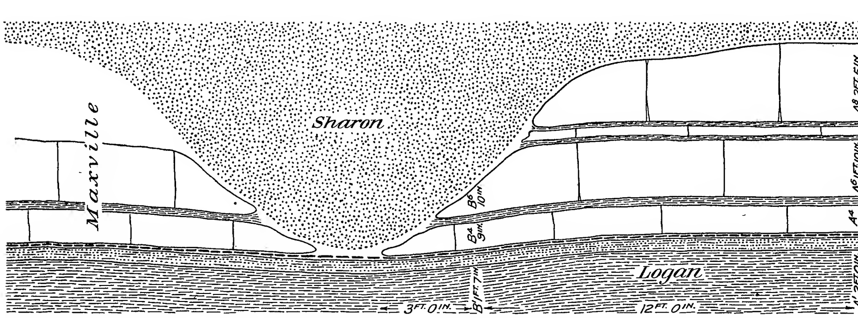


Fig. 2.—A "fossil" valley. A sketch of the south bank of Kents Run at Opera, showing a pre-Pottsville valley in the Maxville limestone filled with Sharon sandstone.

and the base of the Sharon is seen to rise. This then is a natural cross section of the walls (limestone) and filling (sandstone) of an ancient pre-Pottsville valley. It shows that the thickness of the limestone in the center of the old valley is practically zero while at the sides, fifteen feet away, it is at least five and one-half feet. Fig. 2 probably shows these features more clearly.

A few hundred yards below the Opera Covered Bridge an exposure shows the top and bottom contacts of the Maxville limestone. The following section was measured at this place:

Section of the west bank of Kents Run a few hundred yards below Opera Bridge.

	Ft.	In.	Ft.	In.
Pottsville formation			0	3
C9—Iron ore, clinging in places to the top of the limestone. Covered above.				
Maxville limestone			13	0
C8—Layer of harder and darker limestone	0	5		
C7—Massive layer of buff, argillaceous limestone, which may break up into a number of layers and which shatters badly upon weathering	6	8		
C6—Irregular shaly parting	0	1 ±		
C5—Irregular layer of buff, argillaceous limestone, which may break up into other layers	2	10		
C4—Irregular shaly parting	0	1 ±		
C3—Layer of buff argillaceous limestone with an irregular upper bedding plane	2	11		
Logan formation			4	
C2—Argillaceous to arenaceous, soft buff shales	1	0		
C1—Interval covered to water level	3	3		

The Maxville limestone in this section is thirteen feet in thickness. At the forks of the highway, one or two hundred yards above the Opera Covered Bridge, is an exposure in which the lower contact is a few feet above the water, and in which the upper one is not shown, but is probably near the top of the exposure. The bank is sufficiently high, however, to also expose thirteen feet of limestone, and these are the maximum thicknesses measured in this vicinity.

The limestone is exposed in the banks of the run almost continuously for two miles below Opera Covered Bridge, but both contacts were not found below the last section. In the lower part of this distance the top contact reaches water level, and the water flows over the wavy iron stained top of the stratum.

About four miles above White Cottage and two miles below Opera Covered Bridge, is another covered bridge across Kents Run. At this

point, a small tributary is received from the north, and about a quarter of a mile up this branch two wells have been drilled for oil by the Kents Run and White Cottage Gas and Oil Co. One of these is on the Sales property and the other is twelve hundred feet farther up stream on the farm of Mr. Ford.

Mr. Dollinger of this company informs the writer that the well on the Sales property passed through fourteen to sixteen feet of Maxville limestone at twenty feet from the mouth of the well. The Ford well, twelve hundred feet above, on the other hand, penetrated no lime. Since the latter well is situated up stream from the other and in a narrow valley, it does not seem possible that recent erosion has removed the Maxville limestone at this place. The drill seems to have revealed in the one a pre-Pottsville valley similar to the one just described at Opera, and in the other the Maxville limestone of about the same thickness as at Opera.

About two miles above White Cottage and opposite the home of W. T. Wilkins, is an outcrop of Maxville limestone. This exposure is also the lower half, and is a massive limestone four to six feet in thickness without a bedding plane. In color the stone is brownish and in texture somewhat crystalline.

One mile above White Cottage is the third covered bridge across Kents Run below Opera, or the first above White Cottage. At this point is the residence of Ed. Kroft, and the bridge will be called the Kroft Bridge. In front of the house the following instructive section was made:

Section at the Kroft Residence.

	Ft.	In.	Ft.	In.
Maxville limestone			6	11
D^{10}—Layer of compact dove-colored limestone to top of exposure	0	6		
D^{9}—Shaly parting	0	1		
D^{8}—Layer of compact, dove-colored, fossiliferous limestone. This is probably the layer partly under water in the exposure at Mr. Thompson's	1	9		
D^{7}—Shaly parting	0	1		
D^{6}—Probable top of the shale-nodular zone. Layer of compact, dove-colored, fossiliferous limestone. Contains: 1. Productus cestriensis Worthen 2. Bellerophon sublævis Hall	0	6		
D^{5}—Calcareous shales alternating with thin nodular layers of limestone. Very fossilliferous, containing large numbers of: 1. Productus cestriensis Worthen 2. Seminula subquadrata Hall 3. Straparollus similis Meek and Worthen	1	3		

	Ft.	In.	Ft.	In.
D^4—Probable base of the shale-nodular zone. Layer of bluish, crystalline, fossiliferous limestone, nodular on top....	0	10		
D^3—Soft, argillaceous and calcareous dark shale	0	7		
D^2—Hard, calcareous shale to thin-bedded limestone, the material of the subjacent interval replacing the shales to some extent...................... . .	0	10		
D^1—Blue, fine conglomeratic limestone, or limestone with minute calcareous concretions. Base of exposure under water	0	6?		

The important thing in this section is the presence of the shale-nodular zone, since this is the first place it is found, in descending Kents Run. Being so near water level the zone passes beneath drainage in a much less distance than it did in Jonathan Creek.

Just below the Kroft Bridge is another exposure. In this the shale-nodular zone occurs at water level and is overlain with a few layers of the upper half of the Maxville. These layers have been quarried to a slight extent, exposing quite an area of the shale-nodular zone in the bed of the stream. During high waters the looser material is washed away, leaving large numbers of fossils exposed to view. They are so abundant that those of the softer material can actually be scooped up with a shovel. This is the best collecting place known in the Maxville stratum. The different species found at this place are listed in the following section.

Section at the Kroft Bridge.

	Ft.	In.	Ft.	In.
Maxville limestone			4	10
E^6—Layer of compact, fossiliferous blue limestone to the top of the exposure at flood plain level..........	0	6		
E^5—Soft shaly interval, which weathers out, leaving a space between the sub- and superjacent layers	0	1		
E^4—Massive, compact blue limestone Contains: 1. Bellerophon sublævis Hall. .	2	5		
E^3—Soft shaly interval, which weathers away	0	2		
E^2—Probable top of the shale-nodular zone. Layer of compact blue limestone. Contains: 1. Bellerophon sublævis Hall...	0	8		
E^1—Shales alternating with nodular layers of blue limestone. Very fossiliferous. Containing: 1. Septopora rectistyla Whitfield 2. Fenestella serratula Ulrich 3. Productus cestriensis Worthen				

	Ft.	In.	Ft.	In.
4. Dielasma turgida Hall				
5. Seminula subquadrata Hall				
6. Pinna maxvillensis Whitfield				
7. Straparollus similis Meek and Worthen				
8. Holopea newtonensis Whitfield				
9. Bulimorpha melanoides Whitfield.				
10. Naticopsis ziczac Whitfield				
11. Bellerophon sublævis Hall				
12. Orthoceras randolphense Worthen				
13. Orthoceras okawense ? Worthen				
14. Trilobite unidentified. To water level...............	1	0		

While the exposures are not continuous down stream, yet it is apparent that the shale-nodular zone has dipped below water level before the good exposure of the north bank opposite the home of Mr. R. G. Thompson is reached. At this place a thick layer is seen under water and it seems more than probable that this is the first layer, D^8, above the shale-nodular zone. If it be not this layer it cannot be one far above this zone. The section follows:

Section at the Thompson Residence.

	Ft.	In.	Ft.	In.
Maxville limestone...........................			12	8
F^{11}—Layer of gray limestone...............	1	6		
F^{10}—Layer of crystalline, fossiliferous reddish limestone. Contains:				
1. Bryozoan impression				
2. Productus pileiformis McChesney				
3. Productus cestriensis Worthen				
4. Martinia contracta Meek and Worthen				
5. Pinna maxvillensis Whitfield				
6. Allorisma andrewsi Whitfield				
7. Cephalopod unidentified.....	1	9		
F^9—Layer of fossiliferous, bluish-gray limestone. Contains:				
1. Bryozoan reverse side				
2. Productus pileiformis McChesney				
3. Productus cestriensis Worthen				
4. Martinia contracta Meek and Worthen				
5. Spirifer rockymontanus Marcou	2	0		

	Ft.	In.	Ft.	In.
F^8—Layer of fossiliferous, cherty gray limestone. Contains:				
1. Martinia contracta Meek and Worthen				
2. Dielasma turgida Hall				
3. Trilobite unidentified	0	10		
F^7—Layer of compact, fossiliferous bluish-gray limestone. Contains:				
1. Productus pileiformis McChesney				
2. Productus cestriensis Worthen				
3. Martinia contracta Meek and Worthen				
4. Dielasma turgida Hall				
5. Seminula subquadrata Hall				
6. Derbya crassa ? Meek and Worthen				
7. Bellerophon sublævis Hall				
8. Trilobite unidentified	1	0		
F^6—Layer of compact reddish-gray limestone	0	3		
F^5—Layer of fossiliferous, compact bluish-gray limestone. Contains:				
1. Productus pileiformis McChesney (A)				
2. Productus cestriensis Worthen (C)				
3. Martinia contracta Meek and Worthen				
4. Bellerophon sublævis Hall...	1	0		
F^4—Layer of compact bluish-gray limestone with an occasional fossil...........	1	9		
F^3—Layer of fossiliferous, hard, compact, crystalline limestone. Contains:				
1. Productus pileiformis McChesney				
2. Productus cestriensis Worthen				
3. Pinna maxvillensis ? Whitfield				
4. Bellerophon sublævis Hall...	1	4		
F^2—Layer of fossiliferous bluish limestone...	0	6		
F^1—Layer of bluish, slightly fossiliferous limestone to water level...............	0	9		

The above section will probably be slightly misleading since nothing is said about any shaly partings. Such partings occur, however, between most of the layers. But this exposure has long been subjected to the various agencies of weathering, and, situated as it is in the outer bend of the channel, the stream, at high water, has removed the disintegrated shale. The layers, therefore, project from the face of the bank, somewhat independently of each other. The exposure shows the limestone to be the typical upper zone of the stratum.

Attention should also be called to the occurrence of *Productus*

A.—An exposure of the Maxville limestone in Kents Run opposite the Thompson Residence at White Cottage, showing the medium layers of the upper zone.

B.—A view of the Hendricks Quarry on the west bank of the stream at Maxville. The Sharon conglomerate rests disconformably upon the Maxville limestone.

pileiformis in layer F[5]. It is only rarely that specimens of this fossil are found in the Maxville, but at this locality they are very abundant. Large and beautiful specimens can be had in great numbers. The shells are long and expand suddenly in a trunmpet-shaped manner at the anterior end, thus differing markedly from Whitfield's illustrations.

From Mr. Thompson's residence to White Cottage the limestone is more or less exposed all of the way. It is the typical upper zone and is conspicuously stratified and rather fossiliferous. It is a compact, pure limestone of a bluish or bluish-gray color.

In the stream at the east bluff, nearly half way between the Thompson residence and White Cottage, about sixteen inches of the limestone are exposed just beneath the soil. These sixteen inches constitute two layers which are rather fossiliferous and so exposed that collecting is facilitated. The following is a list of specimens from this place:

1. Martinia contracta Meek and Worthen
2. Productus pileiformis McChesney
3. Dielasma turgida Hall
4. Productus cestriensis Worthen
5. Derbya crassa Meek and Worthen
6. Allorisma maxvillensis Whitfield
7. Schizodus chesterensis ? Meek and Worthen
8. Bellerophon sublævis Hall
9. Bellerophon sp.
10. Bulimorpha melanoides Whitfield
11. Sphærodoma subcorpulentus ? Whitfield
12. Straparollus similis ? Meek and Worthen
13. Naticopsis ziczac Whitfield
14. Nautilus pauper ? Whitfield

At White Cottage the formation has already been described in the Gladstone Mill section. In the town a few wells, which were drilled for water, however, penetrated the limestone. The records of two of these are very suggestive and probably ought, therefore, to be presented.

Section of the drilled well at C. W. Stine's Home.

	Ft.
Soil	8
Compact blue limestone	16±
Shaly rock	1½
Hard blue sandstone, probably had some lime in it	8

Section of the drilled well at J. H. Dolling's Residence.

	Ft.
Gravel or alluvium	20
Compact blue limestone	16
Little shale	0
Blue sandstone	12
White sandstone, white as marble	12
Blue shale not passed through	46½

The sixteen feet of compact limestone unquestionably belong to the Maxville and probably to the upper half. The subjacent shaly rock in either well—of one and a half feet in thickness in the Stine well—is probably the shale-nodular zone. Then arises the question—and it must always be admitted to be a difficult one to interpret well records other than those made by a core drill—to what formation to assign the next two intervals in the Dolling's well? In the churning process the rocks are more or less pulverized. Granting that this is the sandy limestone of the lower half of the Maxville, the little lime could easily be washed away, leaving only the sand. Hence it would be reported as sandstone. Futhermore the sandstone of the second twelve feet is reported as being as white as marble, and no such sandstone is known in the Waverly. The next forty-six and a half feet are blue shales. Both blue shales and blue shales with thin sandstones are found in the upper Waverly to which this interval undoubtedly belongs. The two intervals of twelve feet each are, for the reasons just mentioned, strongly suggestive of the lower half of the Maxville, and if referred to it would give a thickness of forty to forty-one and a half feet for the complete formation. These measurements compare very closely with the thickness of the Maxville at Fultonham as determined by the computations in this paper, and by the well records.

WELLS OF SOUTH FORK OF JONATHAN CREEK AND TRIBUTARIES.

The South Fork of Jonathan Creek rises in Perry County near New Lexington. It flows east and thence north to join Jonathan Creek proper about two miles below, east of, White Cottage. Beyond the junction of the two branches, the stream is known as Moxahala Creek. This name has, also, at times, been applied to the two branches.

As already stated, South Fork in its lower course flows to the north. This portion of the stream is decidedly to the east of Jonathan Creek. The dip of the strata to the east is sufficient to bring the Maxville limestone below drainage before the valley of the former stream is reached. The result is, there are no exposures of this stratum along South Fork. A number of oil wells penetrated the limestone, however, at Sayre, Crooksville and Roseville which are located in this valley.

Mr. O. B. Thompson, of Crooksville, is interested in the gas and oil company of this region. He informed the writer that a well was drilled at Sayre and that it passed through about sixty feet of the Maxville. He further states that there have been three wells drilled at Crooksville, and that the limestone was found in all of them, and varies in thickness from fifty to sixty feet.

Mr. J. H. Been, of Roseville, states that about sixteen wells have been drilled in and about Roseville. The Maxville limestone was found in all of them, and varies from about twenty-eight to forty-seven feet in thickness.

EXPOSURES OF RUSH CREEK AND TRIBUTARIES.

Rush Creek rises in Thorne, the northwestern township of Perry County, and after various wanderings flows south through Rushville to Bremen. At the latter point it crosses the preglacial valley, which extends from New Lexington to Lancaster, and receives Little Rush Creek from the east. From here it continues the southerly course for some miles and then a westerly one to the Hocking River at Sugar Grove.

Little Rush Creek also rises in Perry County, at a point a few miles east of New Lexington. It flows practically due west to its confluence with Rush Creek at Bremen. Through the most of its course it meanders lazily through the old glacial filled valley. The tributaries of this and the main branch and the hills at their headwaters furnish a number of exposures of Maxville limestone.

The Zanesville-Maysville Pike extends southwest from Somerset to Rushville. A half mile south of the pike, and parallel with it for some five miles, is the "State Road." Three and a half miles east of Rushville Station, and at J. S. Shafer's residence, the "State Road" crosses Jockey Hollow. The Maxville limestone is found in the headwaters of three of its branches. Although these exposures are not the nearest to those of Jonathan Creek, by some three miles, they will be described first, as both contacts are shown here.

Section of the east gully of Jockey Hollow at the Shafer Residence.

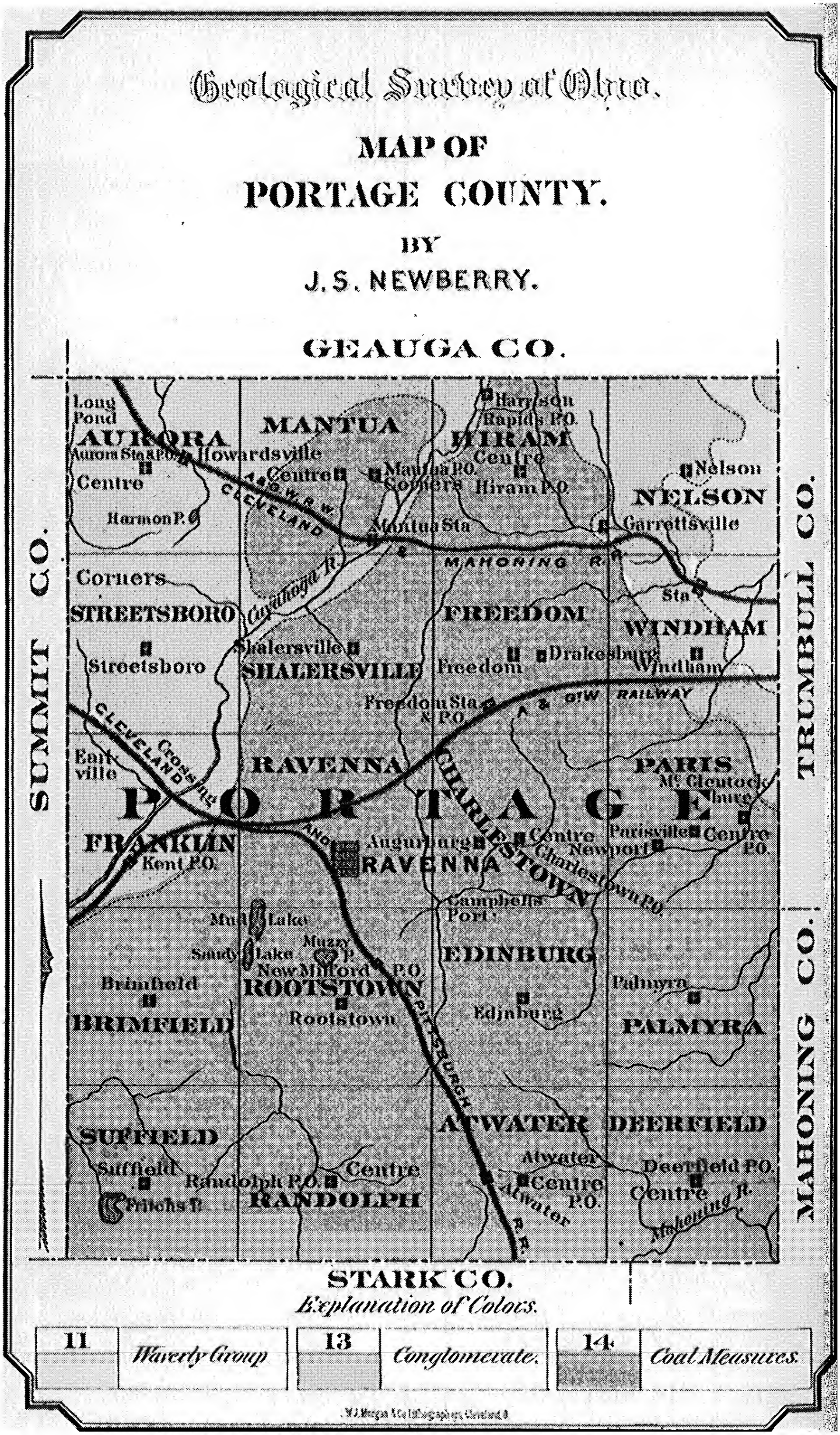
	Ft.	In.	Ft.	In.
Pottsville shales shown farther up the gully.				
Maxville limestone..........................			19	7
A^6—Partly covered at base. Upper part poorly exposed. Impure yellowish or buff limestone, without conspicuous bedding planes. Badly shattered, due to weathering, and markedly different from A^5 and A^4..................	15	0		
A^5—Medium to thin, even-bedded, grayish to yellowish sandstone with lime or impure limestone with sand. The rock is brecciated, and contains pieces of pure, compact, fossiliferous limestone. Some pieces reach the magnitude of 3 by 7 inches and are fossiliferous......	3	10		
A^4—Layer of yellowish sandstone with some lime or impure limestone with sand, and with an even top and an uneven base. Brecciated with pieces of pure compact limestone of much darker color than the usual color of the Maxville. Varies from one foot ten inches to.............................	0	9		

Probable Disconformity.

	Ft.	In.	Ft.	In.
Rushville "group"			23	6
A³—Soft, argillaceous shale, bluish-gray to red in color. Some is slightly arenaceous and contains *Taonurus*. The upper surface is uneven and jointed. The joints are often filled with yellowish sandy material, forming "sandstone dykes"	17	0		
A²—Mostly all covered, some soft, argillaceous blue shale.	5	6		
A¹—Layer of reddish to brownish stone, which in places is a crystalline limestone with Crinoid stems, and in others is ferruginous with but little lime. To base of section at the confluence of the two branches	1	0		
Shales and fine-grained sandstones containing *Taonurus* farther down stream.				

Section of the west gully of Jockey Hollow at the Shafer Residence.

	Ft.	In.	Ft.	In.
Pottsville formation			6	3
B¹⁵—Arenaceous, dark shales to top of exposure below the road	3	0		
B¹⁴—Coal horizon	0	2		
B¹³—Impure fire-clay.	2	10		
B¹²—Covered. At one place there appears to be a layer of iron ore at this horizon.	0	3		
Maxville limestone total thickness			21	
B¹¹—Indistinctly-bedded, impure, argillaceous limestone. Weathers to a yellowish or buff color. Contains: 1. Productus sp	8	0		
B¹⁰—Soft, slightly arenaceous, yellowish shale	0	4		
B⁹—Indistinctly-bedded, impure, argillaceous limestone, weathers to a yellowish or buff color. 1. Productus cestriensis Worthen (Robust forms like those from Cut No. 4, F.)	6	3		
B⁸—Medium-bedded, compact, bluish limestone. One Bellerophon ? observed.	2	9		
B⁷—Soft, argillaceous, blue shale	0	4		
B⁶—Layer of pure, compact, bluish limestone with an occasional small, angular piece of darker limestone. Weathers into nodular-like pieces.	1	10		


Geological Survey of Ohio.
MAP OF
PORTAGE COUNTY.
BY
J. S. NEWBERRY.
GEAUGA CO.
SUMMIT CO.
TRUMBULL CO.
MAHONING CO.
STARK CO.
PORTAGE
AURORA
MANTUA
HIRAM
NELSON
STREETSBORO
SHALERSVILLE
FREEDOM
WINDHAM
FRANKLIN
RAVENNA
CHARLESTOWN
PARIS
BRIMFIELD
ROOTSTOWN
EDINBURG
PALMYRA
SUFFIELD
RANDOLPH
ATWATER
DEERFIELD
Long Pond
Howardsville
Centre
Harmon P.O.
Mantua P.O.
Corners
Harrison Rapids P.O.
Hiram P.O.
Nelson
Garrettsville
Mantua Sta
MAHONING R.R.
Cuyahoga R.
Streetsboro
Freedom
Drakesburg
Windham
Freedom Sta & P.O.
A & G.W. RAILWAY
CLEVELAND
Crossing
Earlville
Mc Clentock burg
Kent P.O.
Augurburg
RAVENNA
Charlestown P.O.
Parisville
Newport
Campbells Port
Mud Lake
Sandy Lake
New Milford P.O.
Brimfield
Rootstown
Edinburg
Palmyra
PITTSBURGH
Suffield
Randolph P.O.
Atwater
Deerfield P.O.
Mahoning R.
Explanation of Colors.
11 Waverly Group
13 Conglomerate.
14 Coal Measures.

	Ft.	In.	Ft.	In.
B^5—Soft, argillaceous blue shale	0	2		
B^4—Sandstone with some lime or impure limestone with sand. Brecciated, with some pieces of compact, dark limestone. Top even and shaly, remaining portion thick with uneven base. In 8 feet it varies from 2 feet 9 inches to	1	9		
Disconformity or contemporaneous erosion.				
Rushville "group"			23	8
B^3—Soft, argillaceous blue shale with uneven top. Joints filled with the same kind of material as B^4 and this material also extends from the joints along the bedding-planes for a short distance	1	8		
B^2—Mostly covered, some soft argillaceous shale	21	0		
B^1—The same layer as described under A^1....	1	0		

More than the usual amount of interest attaches itself to these two sections, because of the excellent exposures of the basal contact of the Maxville limestone. In each one the subjacent shaly interval, A^3 or B^3, as the case may be, has an uneven top. These shales are jointed, and the joints are filled with the same kind of material as that composing the basal intervals, A^4 and B^5, of the Maxville. The same material was forced out from the joints and between the shales for a short distance, as illustrated in figure 3.

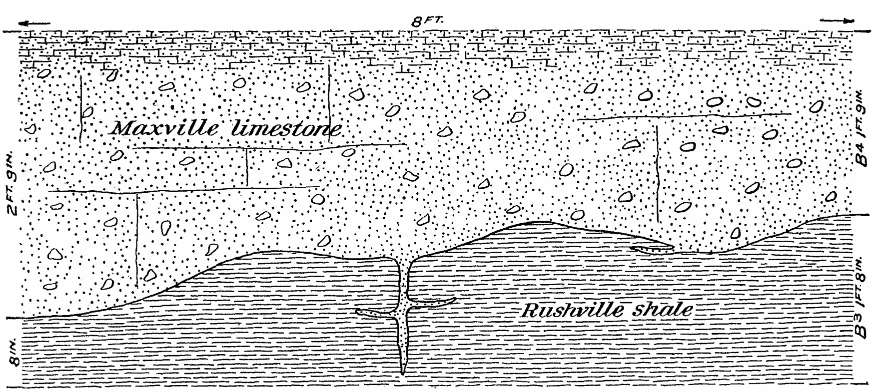


Fig. 3.—A sketch of the Maxville limestone and Rushville shales in Jockey Hollow. Note the uneven contact and that the joints and cracks of the Rushville are filled with the same material as that which makes up the sandy brecciated limestone of the superjacent Maxville.

The basal layer of the Maxville, A^4, in the first section varies from nine inches to one foot and ten inches within the limits of the exposure.

In the second section, the basal layer, B^4, varies from one foot and nine inches to two feet and nine inches within a horizontal distance of eight feet. In both cases the top is even; the variation in thickness being due to an uneven base. From the variations alone it is hard to decide whether this is a case of disconformity or contemporaneous erosion. The filled joints might suggest sun cracks and shallow water during the deposition of the shales, and hence contemporaneous erosion. The joints are not, however, of the usual sun crack variety. Furthermore, data will presently be presented, which further supports the disconformity theory.

When these exposures were first visited, the writer did not include the brecciated calcareous sandstone or sandy limestone, A^4 and A^5 and B^4, in the Maxville limestone, since it differs so markedly from that found in the base of the stratum along Jonathan Creek. Andrews likewise excluded it from the Maxville.[1] More careful study has convinced the writer that it belongs to the Maxville and that its presence is of the utmost significance. Many of the angular pieces in the breccia are limestone. Lithologically they are extremely different from the impure limestone which makes up the mass of the breccia. They are pure, compact limestone and mostly of a color darker than that of the Maxville. Whence is the origin of these angular limestone pieces? Their source could not have been distant or they would have become rounded in transportation. If it were near, then Ohio must have had a Mississippian limestone, other than the Maxville, of which they alone are the representatives. The basal contact, then, is one of disconformity like unto that at the top, rather than contemporaneous erosion.

Aside from the brecciated limestone, B^4, the stratum exposed in the second section is undoubtedly the lower half of the Maxville. On the whole it is a rather impure limestone without distinct bedding-planes. It contains a few badly distorted specimens of the rather robust forms of *Productus cestriensis*. Otherwise it is practically barren. The presence of iron causes the three upper intervals, B^9, B^{10}, and B^{11}, to take on a yellowish or buff tinge, after being subjected to the elements. In this vicinity, and about Maxville, this is called the ''buff stone'' and that below, the ''blue stone.''

The twenty-three to twenty-four feet of shales underlying the limestone are also new. Andrews applied the term Rushville group[2] to a stratum of shales occurring between the Logan and the Maxville somewhere in the vicinity of Rushville without locating the type section. These shales in Jockey Hollow undoubtedly belong to the upper part of the group defined by Andrews.

[1]Andrews, E. B. Discovery of a New Group of Lower Carboniferous Rocks in Southeastern Ohio. *Am. Jour. Sci.*, Vol. XVIII, p. 137. 1879.

[2]Loc. cit.

Since an exposure of the Maxville limestone where it is due is the exception rather than the rule, it seems advisable to at least mention every place of known occurrence. In another branch of Jockey Hollow about one-eighth of a mile west of the Shafer residence, is a third exposure, in the lower part of which the stone seems to be fragmental; and in the upper part, to be the "buff limestone." Three miles east of Rushville Station, and a quarter of a mile west of the Shafer home, where a north and south road crosses the "State Road" at the Griffin residence, is a very poor exposure of the limestone. On either side of this north and south road where it unites with the Zanesville and Maysville Pike, at a point half a mile north of the last location, is an old quarry, but each one has so badly fallen in that only a foot or so of the limestone is exposed.

On the Zanesville and Maysville Pike, two hundred yards east of the last place described, is a farm house belonging to G. W. Folk. A like distance north of the house is an old quarry of Maxville limestone. The limestone lies so near the surface that it is badly weathered and does not furnish a satisfactory section. It will, however, be given.

Section of the G. W. Folk Quarry.

	Ft.	In.	Ft.	In.
Sharon conglomerate			0	0
C^3—At about the same horizon as the top of the "Buff limestone" in another part of the quarry are blocks of coarse-grained sandstone, resting upon residual clay	0	0		
Maxville limestone			11	1
C^2—Badly weathered and badly shattered "buff limestone." The weathering has given the stone a decided stratified appearance, but it is probable that the stone was a massive layer as the "buff" was reported to be at Maxville. To top of exposure, which is within three or four feet of the top of the hill	5	6		
C^1—Massive limestone; the lower part blue and with irregular bedding-planes, causing it to appear contorted; the upper part at least stained buff and at least weathered into layers. Base of quarry	5	7		
Two or three specimens of *Productus pileiformis* were collected in this quarry.				

While the close proximity of the limestone to the surface has facilitated the quarrying of the rock, it has also permitted the elements

to work changes which are not desirable to the stratigrapher. The two greatest of these alterations are the shattering of the stone and the change in color. A casual observation of the quarry would leave the impression of abundant stratification, but a study of the same stratum at Maxville and the description of the fresh stone furnished by the owner of one of the quarries at that place, convince one that most of these apparent bedding-planes are due to weathering.

The blocks of Sharon sandstone apparently rest upon residual clay—the probable residue of the upper surface of the Maxville. The base of these blocks seem to be uneven—a condition we should expect to find. A better exposure would no doubt show that they rest disconformably upon the limestone stratum.

A small pit opening, in which are about two and a half feet of bluish-gray shattered limestone, may be seen high up on the east bank of Rush Creek, a half mile north of the Folk quarry, or, more definitely, a half mile north of the Otterbein United Brethren Church. Blocks of Maxville limestone appear in the highway just south of the Ridge School, or about one and a half miles north of the Folk Quarry. These blocks may be from the drift, but their position seems to indicate that they had worked out from the stratum. The formation crosses the highway near the home of Mrs. Alice Baker, which is two and a quarter miles east of Oakthorpe and about half a mile northwest of the Ridge School, but no measurements could be made at this place.

About two miles east of Oakthorpe, and a half mile west of the Baker exposure, is a high hill, the Cover Hill, on which is located Charles Cover's residence. The Maxville limestone was formerly quarried here for road metal, but the face of the quarry is badly covered at the present time. Only two or three feet of the limestone are exposed. The lower part is the "buff limestone." The upper part consists of two layers, the lower one eleven, and the upper one five inches in thickness. Between the two layers is an indistinct, irregular bedding-plane. The stone is badly shattered by weathering since it lies in the very top of the hill. When freshly broken the lower part is a crystalline, bluish-gray stone and the upper two layers are compact, dove-colored limestone resembling lithographic stone.

Prof. G. F. Lamb, of Mt. Union College, examined this exposure before the writer did, and shortly after it had been opened. In his letter dated January 25, 1908, he says: "The whole section obtained was only a little over 7 feet and in 9 different layers of limestone varying in thickness from a fraction of an inch to 1 foot and 4 inches. Scarcely any two of them are alike, varying in purity, compactness, toughness, color. . . . . . . The partings are sand clay and mixtures of these. It is an interesting exposure, as it shows the very changeable character of the Maxville."

It seems quite possible that some of the layers described by Pro-

fessor Lamb were not natural ones, but were the result of weathering, and that the seven feet were not markedly different from the limestone exposed in the Folk Quarry. The changeable character, mentioned in the letter, has often been attributed to the Maxville. But much of this variability has been shown to be due to a comparison of the limestone in two sections in which the lower half was exposed in one and the upper half in the other, rather than to difference in the stratum itself.

One mile northwest of Redington and in the highway opposite J. H. Gordon's is a poor exposure of Maxville limestone. In the lower part of the exposure the limestone is impure, sandy and brecciated. Some of the larger pieces in the breccia reach a length of three or four inches and are compact, pure, dark limestone. This lower portion is very similar to the lower part of the stratum in Jockey Hollow. Higher, the blocks are impure, bluish limestone, but most of the lime has been leached out, leaving a porous, sandy rock of a brownish color. Near the top, the limestone seems purer, at least it is free from the coarser sand, and weathers to a "buff." Several feet of black, bituminous Pottsville shale apparently rest disconformably upon the stratum. From the lowest limestone block to the upper contact of the Maxville is an interval of sixteen and a half feet.

A number of the exposures mentioned above are worthless as far as sections are concerned. They do show, however, the distribution of the Maxville in this vicinity; an important thing for a formation so frequently "wanting." Isolated exposures appear over a north and south interval of about four miles and an east and west one of two miles —an isolated "hill of Maxville."

The Junction City Clay Products Company's plant is located on the Baltimore & Ohio Railroad, two miles west of the city after which it was named. The company has two "clay banks," the lower one in the Logan, and the upper one in the Pottsville. The following instructive section was measured in the lower quarry.

Section of the Junction City Clay Products Company's Lower Quarry.

	Ft.	In.	Ft.	In.
Immediately above is residual subsoil, whereas 15 or 20 feet above is the base of the upper quarry where fire-clay and shale of Pottsville age are used.				
Sharon conglomerate			2	6
D^2—Layer of coarse-grained sandstone, the base of which is conglomeratic and uneven. Although the face of the quarry was badly plastered by the wash from above, yet this layer apparently rests disconformably upon the next interval.				

	Ft.	In.	Ft.	In.
Logan formation............................			10	6
D[1]—Medium to shaly-bedded, fine-grained buff sandstones to base of exposure, but not of the quarry.				

This exposure is located about three miles southeast of the nearest outcrops of the Maxville limestone, namely, those in Jockey Hollow. And in it the limestone was completely removed before the Sharon was deposited. The next exposures in which the Maxville is present are those of the Monday Creek drainage system, near Maxville, about seven miles still farther to the south.

EXPOSURES ALONG LITTLE MONDAY CREEK AND ITS TRIBUTARIES.

Little Monday Creek rises in Jackson Township, Perry County, at a point about three miles southeast of Junction City. It flows in a southwesterly direction to a point near Webb Summit, where it turns to the southeast and, at Kachelmacher, enters Monday Creek proper. The upper part of the main stream has a southerly course, but after the union of the two branches the resultant stream maintains the southeasterly course of the smaller one and empties into the Hocking River below Nelsonville.

The valley of Little Monday is well within the limits of the Pennsylvanian series, but the stream has cut sufficiently deep, though, to penetrate the Logan sandstone and shale. Along the stream are a number of exposures of the Maxville limestone. These outcrops are in the vicinity of Maxville, the type locality.

The first one of these exposures is in one of the tributaries of Little Monday, a mile north of Maxville. It occurs in the bed of the stream just below James Stimmel's residence. Although only a few inches are exposed vertically, the areal extent is sufficient to show a very important outcrop.

Section of the small stream near the Stimmel Residence.

	Ft.	In.	Ft.	In.
Pottsville formation.........................			1	3
A[3]—Massive irregular-bedded sandstone exposed 5 feet up stream from the limestone. Exact contact not shown since it is under water.				
Maxville limestone			1	3
A[2]—Shale-nodular zone. Layer of compact bluish-gray limestone which breaks up into rectangular blocks or nodular-like blocks on weathering. Fossiliferous........................	0	6		

	Ft.	In.	Ft.	In.
A^1—Shale-nodular zone. Blue shale with nodules of limestone scattered through it. Fossiliferous. A harder layer apparently lies below. To base of exposure........................	0	9		

The following fossils were collected in the two intervals, A^1 and A^2, of the Maxville:

1. Productus cestriensis Worthen
2. Dielasma turgida Hall
3. Seminula subquadrata Hall
4. Allorisma maxvillensis Whitfield
5. Allorisma andrewsi Whitfield
6. Straparollus similis Meek and Worthen
7. Bulimorpha melanoides Whitfield
8. Bellerophon sublævis Hall
9. Cephalopod unidentified.

As already stated, the limestone exists in the very bed of the stream and does not lend itself to easy measurement, but the figures given above are believed to be about correct. A rather large number of species and of individuals of certain species for the Maxville are found here, *Bellerophon sublævis* being very abundant. The abundance of fossils and the appearance in general suggest the shale-nodular zone of the Jonathan Creek and Kent Run sections. To this zone both intervals are referred, although it must be admitted that there is some uncertainty, due to the stratum being covered below.

Lime Kiln Hollow is the name of the small tributary of Little Monday at Maxville. On either side of the stream for two or three hundred yards above the town, the Maxville limestone was formerly quarried for lime. The faces of these old quarries have long since been covered over with surface material. The only remaining exposure is along the bed and bank of the stream, where the following section was made.

Section of Lime Kiln Hollow.

	Ft.	In.	Ft.	In.
Maxville limestone			6	1
B^7—Compact dove-colored limestone apparently composing a single layer.........	0	10		
B^6—Compact dove-colored limestone apparently forming a single layer	1	0		
B^5—Compact dove-colored limestone	0	9		
B^4—Layer of compact pink or dove-colored limestone, resting upon and partaking of the form of the contorted layer below. The layer is badly shattered and the cracks are filled				

	Ft.	In.	Ft.	In.
with calcite in the form of veins....	0	4±		
B^3—Peculiar, contorted layer of brownish-gray limestone. Contains quartz of fantastic shapes, not exactly angular pieces, yet resembling them......	0	9±		
B^2—Layer of brownish-gray crystalline limestone..........................	1	2		
B^1—Impure dark-brown limestone in hard, thin, wavy layers. To base of exposure under water	1	3		

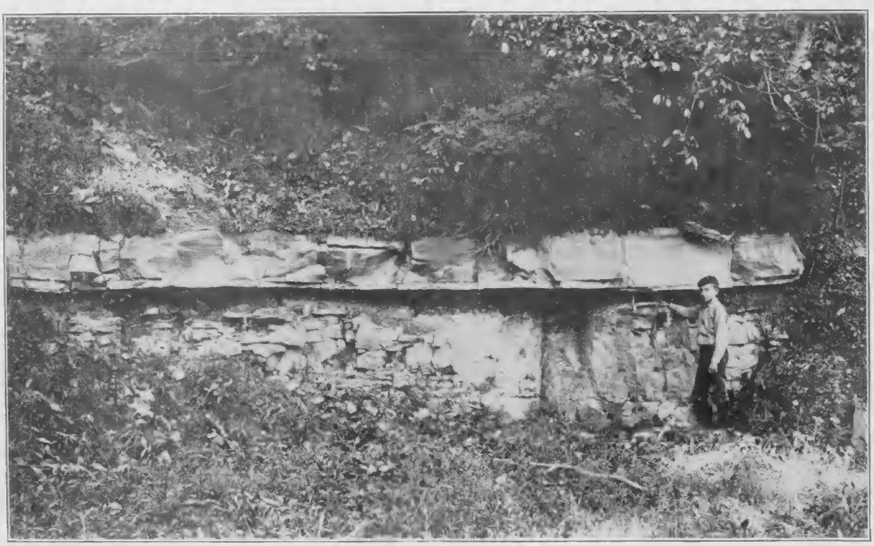
The rather peculiar texture and structure of the stone and the absence of both contacts make the correlation of the zones at this place a somewhat delicate task. The third layer, B^3, is not only peculiarly contorted, but contains quartz in fantastic shapes, and this quartz seems to be quartz of replacement rather than grains of quartz sand. The fourth layer, B^4, partakes of the contorted form of the third layer, B^3, upon which it rests, and is badly shattered, the cracks being filled with calcite veins. These are features which are usually absent in the Maxville. Farther up stream, the limestone above the third layer seems to be purer and lighter in color and in one place to be thrown into a small anticlinal fold. This lighter portion is said to have been the part used for lime and to have measured ten feet in thickness before it was partly covered. The absence of the contacts, as already stated, and also that of the fossils, except a few exceedingly poorly preserved ones which are unidentifiable Bryozoans and Brachiopods, render correlation so uncertain that it will not be attempted.

Another small stream enters Little Monday Creek from the north, at the residence of Daniel Hendricks, a half mile below Maxville. The limestone has been quarried on both sides of this stream for quite a distance. The nearest quarry is on the eastern side about two or three hundred yards above the residence. This is also the most recently operated quarry and hence contains the best exposure.

Section of the Hendricks Quarry on the east bank.

	Ft.	In.	Ft.	In.
Sharon member..............................			8	1
C^{13}—Two or three layers of coarse-grained sandstone........................	1	4		
C^{12}—Arenaceous blue shale; usually with iron ore at the base	6	1		
C^{11}—"Graystone." Layer of calcereous sandstone. The layer has an uneven base when C^{10} and C^9 are present, but these are mostly absent, and then the layer has a regular base. In the latter case it appears to rest conformably upon the Maxville. Varies from 1 foot 9 inches to	0	8		

A.—A view of the Maxville limestone and the Sharon member in the Hendricks Quarry on the east bank of the valley at Maxville. The Sharon seemingly rests conformably upon the Maxville at every place in the quarry except this one where the base clearly rises to admit the small remnant of a limestone layer.



B.—Contact of the Maxville limestone and the Sharon member in the same Hendricks Quarry at Maxville. The same basal layer of the Sharon as the one in A. A most beautiful illustration of deceptive conformity.

Disconformity.

	Ft.	In.	Ft.	In.
Maxville limestone			14	8
C^{10}—Shale, absent except at one place.......	0	2		
C^{9}—Layer of compact blue ("buff") limestone, with slightly uneven base, absent except at one place	1	3		
C^{8}—Soft shale with a peculiar quartz layer in the base. This forms the top of the stratum throughout nearly all of the quarry. From 9 inches to	0	4		
C^{7}—"Buff stone." Compact blue limestone which weathers to a red or buff on exposure, due to the iron present in it. Shatters badly on exposure, but said to be a single layer................	4	10		
C^{6}—"Blue stone." Compact blue limestone with a few irregular bedding-planes. All exposed except a few inches near the base. To base of quarry.......	4	7		
C^{5}—Zone, with the base of shale, the middle of peculiar quartz material like that in Lime Kiln Hollow, and the top of white limestone. All badly contorted	1	3		
C^{4}—Layer of gray limestone with contorted base	1	1		
C^{3}—Limestone, poorly exposed	1	2		
Undetermined			9	6
C^{2}—Internal covered.				
Logan formation............................			12	3
C^{1}—Medium to shaly bedded, fine-grained, buff sandstones. Ripple-marked. To base of exposure above the barn.				

Layer C^{11} contains considerable lime—said to be twenty per cent.—and in all places in the quarry except one, and that at first was overlooked, has an even base and top. For these reasons it was at first included in the Maxville limestone. More careful study has revealed the presence at one place of a layer of limestone and a zone of shale, C^{9} and C^{10}, in the top of the Maxville and the rise in the base of layer C^{11} to admit them. Layer C^{11}, therefore, has been made the basal member of the Sharon and undoubtedly rests disconformably upon the Maxville. These features, namely, the uneven base of layer C^{11} and the presence of the intervals C^{10} and C^{9} in one place and layer C^{11} resting in deceptive conformity upon the zone C^{8} due to the absence of the intervals C^{10} and C^{9} in another, are respectively shown in A and B of Pl. XI.

On the west bank of the stream, above the quarry just described, are a number of smaller and older quarries. In these the Sharon is not only a massive sandstone, but has a very irregular base. These changes are clearly brought out in the following section.

Section of the Hendricks Quarry on the west bank.

	Ft.	In.	Ft.	In.
Sharon conglomerate			1	7
D⁴—Massive coarse-grained sandstone with plant markings. Twelve feet to the east the base of the sandstone passes beneath cover within six inches of the base of the exposure				
Disconformity.				
Maxville limestone			8	6
D³—Covered, but probably the base of the Sharon also sloped toward the face of the quarry, that is to the south, and rested directly upon this sloping surface	1	11		
D²—"Buff stone." Blue limestone turning to red or buff when exposed, due to the presence of iron. Badly shattered, but said to be without bedding planes	3	5		
D¹—"Blue stone." Compact blue limestone with indistinct, irregular bedding-planes. To base of exposure	3	2		

This exposure reveals a most beautiful case of disconformity and is nicely shown in Pl. X, B. Where the section was made the Maxville is eight and a half feet and the Sharon one foot and seven inches in thickness. Twelve feet to the east the base of the Sharon passes beneath the filling of the quarry and to within six inches of the base of the exposure, as illustrated in the following sketch (Fig. 4).

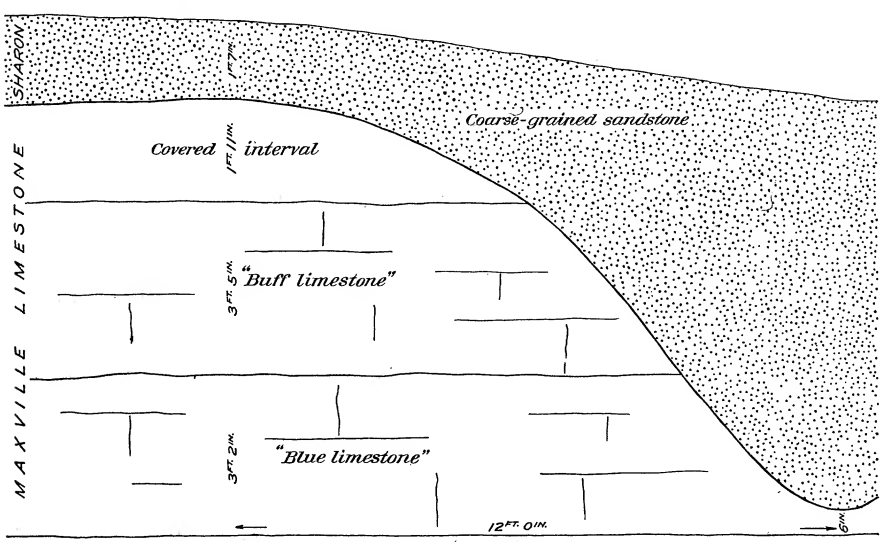


Fig. 4.—The disconformity between the Maxville limestone and the Sharon conglomerate in the Hendricks Quarry on the west bank at Maxville. A sketch of the same rocks as those shown in the photograph in Plate X, B.

The Maxville has thus suffered at least eight feet of erosion in a horizontal distance of twelve feet. The exposure extends far enough to the east to show that the base of the Sharon begins to rise almost as abruptly as it descended. In the Maxville limestone during the pre-Pennsylvanian age, then, this was an old gully, the life of which was brought to a sudden close by the sediments of Sharon age. About twenty feet to the west the base of the Sharon descends to at least the top of the "blue stone." Here then was another gully. Possibly the two were tributaries—brothers. What a story they might reveal if the Sharon were lifted bodily from them, since further erosion is slightly shown farther up stream.

Passing down Little Monday Creek to a point three-fourths of a mile below Maxville or a mile above the Hocking Valley Railway, one reaches a covered bridge. On the east side of the valley, below the bridge, the Maxville was formerly quarried along its crop. This is the old Howdeshell Quarry.

Section of the Howdeshell Quarry.

	Ft.	In.	Ft.	In.
Sharon conglomerate			3	11
E^5—Layer of gray sandstone with dark stains. To top of exposure	1	10		
E^4—Grayish-black shale with an occasional quartz pebble	1	4		
E^3—Two layers of iron bearing sandstone alternating with arenaceous shale	0	9		
Maxville limestone			4	8
E^2—"Buff stone." Layer of grayish limestone which turns red or buff on exposure. A few inches of the top mixed with, and stained by, iron ore.	3	10		
E^1—Layer of compact, drab limestone	0	10		

On the west side of Little Monday Creek, a half mile north of the Hocking Valley Railway, is the Culver Lime Kiln. Here, in days gone by, the Maxville limestone was burned for lime. It is a later kiln than the one or ones at Maxville, but in either case the lime was transported overland by wagons. The stack stands as a monument to a once rather widely disseminated industry—the death of which is but another tragedy of cheaper railroad transportation.

The Maxville was quarried at the kiln, but the old quarries have filled in with mantle rock. A few hundred yards north or the kiln, about six feet of the limestone is exposed in a small gully, but neither contact is shown. In the upper part of the exposure the limestone is compact and blue and in the lower it is less compact and darker. A loose block showed that peculiar quartz structure already noted at Maxville.

Just east of Webb Summit a cut carries the Hocking Valley Railway from the drainage system of Little Monday Creek into that of the Hocking River. Although the eastern end of this cut is but half a mile south of the last exposure, that is, the one at the Culver Lime Kiln, yet the Maxville has been completely removed and the Sharon rests disconformably upon the Logan. These facts are clearly shown in the following section:

Section of the Webb Summit Cut.

	Ft.	In.	Ft.	In.
Sharon conglomerate			1	4
F3—Coarse-grained sandstone above and conglomerate below. Contains quartz pebbles, the size of the finger tips. Base slightly uneven				
Disconformity.				
Logan formation			10	9
F2—Medium-bedded to shaly, fine-grained, buff sandstone	8	6		
F1—Covered interval, to the Hocking Valley Railway track	2	3		

EXPOSURE ON THREE MILE RUN.

The next and last exposure of the Maxville limestone in the Northern Area is in the valley of Three Mile Run. This stream rises in Falls Township, Hocking County, about a mile south of Webb Summit. It flows south and empties into Hocking River at a point three miles below Logan.

The exposure is on the west bank of the run, just east of Smith Chapel, and is an old quarry where limestone was obtained for furnace flux for old Five Mile or Union Furnace, located five or six miles to the south. Unfortunately the quarry is in an old terrace covered with glacial outwash material and most, if not all, of the overlying Pennsylvanian rocks have been swept away. The face of the old quarry is, furthermore, badly covered, but in spite of this the following interesting section was obtained.

Section of Three Mile Run at Smith Chapel.

	Ft.	In.	Ft.	In.
Maxville limestone			8	10
Apparently shale above..				
A10—Layer of bluish-gray limestone. The fossils are: 1. Productus cestriensis Worthen 2. Straparollus similis Meek and Worthen. 3. Bellerophon sublævis Hall	0	5		
A9—Shaly parting	0	1		

	Ft.	In.	Ft.	In.
A^8—Layer of slightly argillaceous, bluish-gray limestone. Contains: 1. Bellerophon sublævis ? Hall	1	3		
A^7—Shale-nodular zone. Bluish, argillaceous shales, which somewhat resemble fire-clay, alternating with nodular layers of limestone. Although not so strikingly fossiliferous as the shale-nodular zone at other places yet it is probably this horizon. The following fossils were collected: 1. Productus cestriensis Worthen 2. Dielasma turgida Hall 3. Seminula subquadrata Hall 4. Straparollus similis Meek and Worthen 5. Bellerophon sublævis Hall....	2	7		
A^6—Irregular layer of compact, bluish-gray limestone	1	0		
A^5—Irregular and wavy zone of argillaceous, blue shale........................	0	2±		
A^4—Compact, bluish-gray limestone with a wavy top	0	9		
A^3—Poorly exposed, but mostly shale with nodular layers of blue limestone	0	11		
A^2—Compact bluish-gray limestone, the upper surface of which breaks up badly on exposure.........................	1	0		
A^1—Compact, bluish-gray limestone, with an uneven lower surface. The layer itself may be due to a split from the superjacent layer. To base of old quarry	0	8		

Although not all that could be desired, yet this is a most interesting section. A complete exposure with top and bottom contacts shown would be more conclusive evidence in any question of statigraphy, still the section is suggestive. The blue shales alternating with nodular layers of limestone in A^7 resemble the shale-nodular zone to say the least. These shales are also rather fossiliferous, another point in favor of this identification. The medium layers of fossiliferous limestone, A^{10} and A^8, with a shaly parting, A^9, all of which are found above this zone of shales and nodular limestone (A^7), are very much like those layers and partings of the upper zone of the Maxville as exposed along Jonathan Creek. The evidence seems to be all in favor of referring the interval A^7 to the shale-nodular zone.

THE CENTRAL AREA.

The central area extends from Smith Chapel at Logan to Hamden. It includes the southern half of Hocking and the whole of Vinton counties.

Days of search in this field failed to reveal any exposures of the Maxville limestone.

Southwest of Blackjack, a mile and a half to two miles, is the residence of Charles Haggel. In front of his house a small run empties into one of the branches of Pine Creek. The upper Waverly and lower Pennsylvanian rocks are more or less exposed up this run. No Maxville is found here between the Logan and Pottsville, although a very impure limestone exists in the upper part of the Logan. This at first was thought to be a possiple off-shore, sandy representative of the Maxville limestone, for it was believed, by the author, that a stratum of isolated patches of limestone with so wide a distribution must once have been continuous. These patches, it was conceived, might be connected by arenaceous limestone or calcareous sandstone or even by sandstone. Later study has shown the isolated patches to be the result of pre-Pennsylvanian erosion and that these impure limestones in the Logan are in no way connected with the Maxville.

South of the last named place, two and a half or three miles, North Fork of Queer Creek leaves a comparatively wide valley and enters a gorge of Black Hand conglomerate. The passage is over a precipitous face of conglomerate, sixty or eighty feet in height. This is Cedar Falls, and at the falls the creek receives a small tributary from the south. Along this the Logan and Pottsville are exposed, but no Maxville limestone is to be found. The Logan, however, contains some layers of impure sandy limestone.

Ash Cave is a semi-circular or semi-conical cavern in the Black Hand, over which a small tributary of the South Fork of Queer Creek plunges for a sheer drop of ninety-three feet. The cave is located about two miles southwest of Cedar Falls. As one ascends South Fork from the cave the Black Hand and Logan formations are successively mounted and the Pottsville horizon reached at Hue Postoffice. The Maxville is wanting, and the Logan, as usual, contains a few layers of impure limestone or calcareous sandstone.

In this vicinity, about twenty or thirty feet above the very thick conglomerate, appears another conglomerate a few feet in thickness. Mr. Hyde, who is studying the Waverly in this part of the state, claims that this second stratum belongs within the limits of the Logan formation. Should it be the No. II conglomerate forming the top of the Black Hand, then some twenty or thirty feet must be taken from the base of the Logan and added to the top of the Black Hand. The result is a rather thin—as low as fifty or sixty feet—stratum of Logan. A reduced thickness for the Logan is, however, to be expected in this region, since the vigorous erosion, which removed all of the Maxville, more than probably removed a considerable amount of the top of the Logan.

The headwaters of the Middle Fork of Salt Creek are located in Section 14, Jackson Township, Vinton County, about three miles south of those of the South Fork of Queer Creek. In passing down stream one descends the geological scale from the Pennsylvanian to the Waverly series. The rocks are mostly exposed, but the Maxville is not present.

At the Mt. Olive covered bridge, a mile north of Allensville, the Middle Fork of Salt Creek receives a tributary from the east. The rocks are exposed at the confluence and more or less throughout the course of the smaller stream, and especially is this true of the upper half of the creek. The Sharon is here developed as a massive conglomerate. Twenty-two feet are exposed at one place in a vertical section where neither contact is shown, whereas the barometer gave thirty-five to forty-five feet for its complete thickness. It rests disconformably upon the Logan without any remnants of the Maxville limestone.

From the south another tributary enters Middle Fork at Allensville. The upper Waverly and Sharon are also exposed in this tributary. While the exposure at the contact is not the most satisfactory it is sufficient to show the absence of the Maxville.

Other places where the rocks of the Pennsylvanian series rest disconformably upon those of the Waverly could be cited within the Central Area. This scarcely seems necessary since it would only be a repetition of the conditions found in the exposures mentioned above. And furthermore, a point within seven miles of Hamden, which is located in the northern edge of the Southern Area, has now been reached.

THE SOUTHERN AREA.

The Southern Area extends from Hamden on the north to the Kentucky side of the Ohio River on the south. It embraces the margin of Vinton and the whole of Jackson and Scioto counties. Within it are a few small and widely separated areas of the Maxville limestone.

LITTLE RACCOON CREEK EXPOSURES.

Little Raccoon Creek rises at a point about two miles west of McArthur. Its course is mostly a little east of south through Hamden and Wellston to its confluence with Raccoon Creek, south of Vinton. It lies wholly within the limits of the Pennsylvanian rocks, but it has cut sufficiently deep into the strata at Hamden to reach the Maxville limestone and the top of the Logan formation, and to thus give us another inlier of Maxville. Unfortunately an old high level stream, Albany River, which swept through here to the southwest in the ages of long ago, removed practically all of the Pennsylvanian rocks down to the Maxville, so that this contact is hard to find. In spite of this, however, a number of interesting and instructive sections were made.

Nearly a mile east of Hamden is a highway bridge across the present stream. Just above the bridge are the remains of old "Reed's Mill." Here, on the west bank, the first section was measured.

Section at Reed's Mill.

	Ft.	In.	Ft.	In.
Pottsville formation			1	9
A^7—Massive, coarse-grained sandstone above, with some lime below, and with nodules of iron. Probably Pottsville...				
Undetermined			1	0
A^6—Interval covered.				
Maxville limestone			18	5
A^5—Coarse-grained, sandy limestone, gray in color	0	5		
A^4—Mostly covered, some arenaceous gray limestone	4	0		
A^3—Massive, coarse-grained, sandy limestone, grayish in color. It is without distinct or any bedding-planes, except those cross-bedded ones which in some places occur near the base of the interval. At places this interval is separated from the subjacent one by a softer zone only, while at other places the two are not separable, and then they form but a single massive layer. The sand consists of pure white grains of quartz. In places the limestone is brecciated	6	6		
A^2—Massive limestone, without definite bedding-planes, but in places it tends to split up and appears slightly cross-bedded. The limestone is gray in color and sandy, the grains being of white quartz. It is also brecciated. the angular pieces in many places consisting of compact, pure limestone of different colors and markedly different from the mass of the stratum. The lower part contains small, irregular nodules of chert	7	6		
Undetermined			2	0
A^1—Interval covered to water level.				

Banks of Maxville limestone are found first on the one and then on the other side of this meandering stream, as one ascends it for a few hundred yards. They are of about the same height as the one in the section and do not show either contact. At a point about four hundred

yards above the site of the old mill, seventeen feet of the Sharon suddenly descend to water level and cut out the Maxville. A few hundred feet still farther up stream the Maxville again appears in the same bank in about its normal thickness. This is conclusive evidence that the upper surface of the Maxville suffered erosion in Paleozoic time and that the Sharon was deposited disconformably upon the limestone.

About four hundred yards below Reed's Mill, Little Raccoon Creek is crossed, in turn, by the Baltimore & Ohio Southwestern Railroad. A hundred yards above the railroad bridge and on the east bank of the stream is an exposure of the Maxville limestone. Here the following section was made, but the water level in this section is slightly higher than it was given in the Reed's Mill section because a small dam has been built at the railroad bridge since the mill section was measured.

Section above the Baltimore & Ohio Southwestern Railroad Bridge.

	Ft.	In.	Ft.	In.
Pottsville formation			0	7
B7—Coarse-grained, brown sandstone with much iron ore, to top of exposure				
Undetermined			5	0
B6—Interval covered				
Maxville limestone			12	0
B5—Coarse sandstone with some calcite, some lime and much iron. This is probably one of the breccia horizons	1	9		
B4—Massive, coarse-grained, sandy limestone, without any distinct bedding-planes, but with some irregular pockets of shale. If the section were more accessible, it might show that it was brecciated	8	0		
B3—Arenaceous gray limestone, cross-bedded, like that at Limeville and Carter Caves, Kentucky	1	9		
B2—Very impure, sandy limestone of a bluish-gray color. It is more indurated than the overlying interval. Contained one Pelecypod shell	0	6		
Undetermined			1	0
B1—Interval covered to water level.				

As previously stated, the last exposure is only one hundred yards above the Baltimore & Ohio Southwestern Railroad bridge. At the east abutment of this bridge, recent excavation has exposed a few feet of the strata. Here the following important section was measured.

Section at the east abutment of the Baltimore & Ohio Southwestern Railroad Bridge.

	Ft.	In.	Ft.	In.
Pottsville formation			2	7
C^6—Black, bituminous shale with coarse arenaceous and ferruginous material at the base. Undoubtedly Pottsville formation. To top of exposure.				
Undetermined			3	2
C^5—Practically covered, but probably shale.				
Logan formation			6	1
C^4—Layer of fine-grained buff sandstone, which may be part of layer C^2	0	6		
C^3—Soft, argillaceous white shale, which may only occur in pockets	0	1		
C^2—Massive layer of fine-grained buff sandstone, which may break up into thin layers	3	0		
C^1—Thin-bedded, fine-grained buff sandstone, with a nodular lentil of iron ore. To present water level, which is two or three feet below the top of the dam	2	6		

Here, then, are two sections within a hundred yards of each other. In the one there are twelve feet of the Maxville exposed and there is a possibility of five or six feet being added to the thickness of the formation. In the other one there is no Maxville exposed and the probabilities are that the covered interval, C^5, of three feet and two inches, belongs to the Pottsville shale, rather than to the Maxville. In short, the Maxville has been either practically or completely removed in the lower section, whereas there are at least twelve feet in the upper one.

The Baltimore & Ohio Southwestern has somewhat recently built a new bridge at this place, and the new abutments and arch approaches are concrete structures. The blocks of the old stone abutments were pushed aside and among them are a number of limestone ones which were quarried from the Maxville. These blocks of limestone are much more accessible for study than is the formation along the banks of the stream, and in them the limestone is mostly sandy and impure, and is commonly brecciated. The sand is a white quartz, the grains of which are rounded. The angular pieces, forming the breccia, are mostly limestone of a different color and of a much purer composition than the matrix of the stratum, and many of them reach a length of one or two inches. Scattered among the other material of the breccia are patches of calcite crystals. In some of the blocks there are irregular pieces of chert similar to those in the Mississippian limestone at Carter's Caves, Kentucky.

When first studied these exposures were rather perplexing, the limestone being so different from the pure upper half or, for that matter, from the argillaceous lower half of the formation as exposed along Jonathan Creek. For this reason the exposures at Hamden were first thought to represent a slightly younger formation. It was conceived that the Maxville had been completely shattered and worked over and into this a new sandy, brecciated limestone stratum of Sharon or pre-Sharon age. Neither were there any fossils to aid in the determination of its age. Later studies of the Mississippian limestone farther to the south show, however, that this is also of Mississippian age, and that the stratum becomes more and more sandy for an ever increasing thickness. The limestone, too, in many places is cross-bedded—a feature that shows more plainly when the stone is subjected to the elements. This cross-bedding is nicely shown at Carter and strikingly at Carter's Caves, Kentucky.

The angular pieces of limestone in the brecciated portions of the formation at Hamden are worthy of special consideration. As previously stated, these and those in the Jockey Hollow exposures are angular and not water worn. Hence their origin must have been a point close at hand. If close at hand, then they must have been derived from another and earlier limestone stratum or from the breaking up of the Maxville's own stratum. If the latter condition were not the actual one, and it probably was not, then Ohio must have had a Mississippian limestone of age younger than the Logan and older than the Maxville.

EXPOSURES OF THE LITTLE SCIOTO RIVER AND TRIBUTARIES.

The headwater streams comprising the Little Scioto River drainage system have their origin in the southern part of Jackson and Pike counties. After their union the river maintains a southerly course. It discharges into the Ohio River at Sciotoville.

One of these tributaries rises just beyond the eastern border of Hamilton Township, Jackson County, and flows southwest and thence west across the township. In Section 24, at the home of Amos (Son of Enoch) Canter, the stream has penetrated the Maxville. At this place the limestone was formerly quarried to a considerable extent for furnace flux and for road metal, but the quarry has recently been converted into a fish pond by means of a dam. Although the water covers most of the stratum, still enough is exposed to give the following important section.

Section of the Canter Quarry.

	Ft.	In.	Ft.	In.
Pottsville formation			7	2
A^5—Bluish, arenaceous shales and shaly sandstone, to top of quarry	3	0		

	Ft.	In.	Ft.	In.
A[4]—Coarse-grained, micaceous sandstone with a trace of iron. In places there are two inches of iron ore above and in places a like amount below the sandstone	0	8 ±		
A[3]—Green, flint fire-clay, the upper part white	2	6		
A[2]—Irregular layer of iron ore, which in some places is nearly all displaced by chert. The ore passes into fire-clay above and into chert below. The chert adheres to the limestone. The top of the iron ore is wavy, and is 9 inches lower in one place than it is at another, three of four feet away. The contact of the chert with the limestone below could not be examined on account of the water. Varies from 1 ft. 4 in. to	1	0		
Maxville limestone			2	0
A[1]—Compact, bluish-gray limestone. Some parts with angular pieces of chert. Water level of the fish pond in the old quarry.				

About two hundred yards below the quarry and at the Canter residence a scarp exposes a little more of the Maxville. The limestone, as shown here, is three feet in thickness and without a bedding plane. It is of a bluish-gray color and contains some chert in its upper surface. Since no fossils are present and since the lower contact is not shown in either the quarry or the scarp, the exact horizon of the stratum cannot be determined, but the massive character and the absence of fossils are suggestive of the St. Louis, as brought out in the correlation portion of this paper.

The well at the Canter residence is only a few feet from the limestone scarp, and the mouth of the well is six or eight feet above the top of the limestone. In digging the well some soil was first encountered and then about ten feet of red clay or fire-clay. The well was continued to a total depth of twenty-three feet without striking any limestone. Since the bottom of the well is at least fifteen feet below the top of the limestone in the scarp, this number must represent the minimum difference in pre-Pottsville erosion at the two places.

The area of this remnant of Maxville is, like many of the others, very small indeed. Down stream it is seen for a few hundred yards. Up stream it soon passes beneath drainage, and from our knowledge of the formation it is not reasonable to suspect that it extends far beneath drainage in this direction.

Frederick Creek rises near South Webster and flows west through Bloom Township, Scioto County, to join the Little Scioto River, just beyond the western border of the township. Its valley is sufficiently deep to expose Mississippian strata for quite a distance within the more general limits of the Pennsylvanian series. The extreme point is a small bank where the highway crosses the clay switch of the Baltimore & Ohio Southwestern Railroad, about opposite the Harbison & Walker Refractories Company's grinding mill. Here the rocks of the following section are exposed:

Section at the Harbison & Walker Mill.

	Ft.	In.	Ft.	In.
Sharon conglomerate			3	0
A[3]—Very coarse conglomerate, apparently with an irregular base	2	6		
A[2]—Soft, argillaceous blue and yellow shale with some sand....................	0	6		
Logan formation............................			2	6
A[1]—Medium to thin-bedded, fine-grained white and buff sandstone, with peculiar long conical depressions.				

In this section the Maxville limestone was completely removed by pre-Pottsville erosion. The last exposure in which it was seen, namely, the Canter Quarry, is located about eight miles to the north. The next place where the limestone is found is on Niner Ridge, which lies about eight or nine miles to the west.

Three miles and a half north of Sciotoville, the Swager Run highway crosses a high hill, known as the Niner Hill. This hill is, in fact, a very narrow east and west ridge—a divide between those tributaries of the Little Scioto River which flow to the northeast, and those which flow to the southeast. Along the very crest of the ridge is a coarse sandstone, and beneath this sandstone in Section 24, Harrison Township, Scioto County, not only was a fire-clay formerly worked, but also the Maxville limestone. This is on the land of the old Harrison Furnace Company, and they used the limestone as a flux in their furnace. Both the fire-clay and limestone banks have pretty badly fallen in, but through the kindness of Mr. J. A. Shump, who aided in locating these old mines and who furnished much useful information, the writer is able to present the two following sections located near each other. In the first exposure a little of the limestone escaped pre-Pottsville erosion, whereas in the second all of it was removed.

West Section of Niner Ridge.

	Ft.	In.	Ft.	In.
B[6]—Soil to top of ridge..................			2	0
Pottsville formation........................			15	11
B[5]—Massive, coarse-grained gray sandstone..	13	2		

	Ft.	In.	Ft.	In.
B[4]—Green, argillaceous clay. At another exposure 20 feet away a foot of white clay with one or two sandstone partings appears at the top	2	0		
B[3]—Interval in which iron ore nodules occur	0	5		
B[2]—Interval of irregular pieces of white chert	0	4		
Maxville limestone			0	6
B[1]—Light-colored limestone, exposed by digging down to it. Mr. Shump worked in this mine in 1867 or 1868. He says, all told, 2½ to 3 feet of compact bluish-gray limestone was mined for furnace flux, but the stratum was not constant and thinned out in places.				

East Section of Niner Ridge.

	Ft.	In.	Ft.	In.
C[6]—Soil to top of the ridge			3	0
Pottsville formation			13	0
C[5]—Massive coarse-grained sandstone	10	0		
C[4]—Green argillaceous shale	0	5		
C[3]—Black argillaceous and carbonaceous shale	1	6		
C[2]—Coal	0	1		
C[1]—Massive, green, flint fire-clay, "bastard fire-clay." Mr. Shump says that, further in, the fire-clay is of a good quality and 2½ to 3 feet thick, and that it occurs at the same vertical (not geological) horizon that the Maxville did in the previous mine. This is the Sharon fire-clay	1	0		

RECORDS OF WELLS ALONG PINE CREEK AND TRIBUTARIES.

Pine Creek rises somewhere in the southern part of Decatur Township, Lawrence County, and flows to the north and thence to the west, leaving the township near its northwest corner. It enters Scioto County at the southeast corner of Bloom Township. After many wanderings in this county, in Lawrence again, and finally again in Scioto, it discharges into the Ohio River near Wheelersburg.

Its lower or northwesterly course is within Mississippian strata, whereas the remainder of its course, on the other hand, is a long way within the limits of the Pennsylvanian series. A number of well borings and a shaft in two of its head water tributaries have, however, penetrated the Maxville horizon. A careful location of the wells and shaft, before the records are given, is important.

A mile southwest of Olive Furnace, the tributary, flowing southwest through the village, enters Pine Creek. At the side of this tribu-

tary just below town, a well was drilled on the land of McGugin & Co. At this same confluence another tributary enters Pine Creek from the northwest. About two miles above the mouth of the second tributary a well was d.illed on the farm of Adam Brandt. A mile and a half above its confluence or a half mile below the Brandt well are the shaft and three wells known as the Harper Shaft and wells.

Mr. Wilber Stout and Mr. C. Ellison McQuigg, former students, very kindly furnished copies of the driller's log of the Brandt and McGugin wells, respectively. Mr. J. L. Harper kindly sent a section of the first well up stream from the shaft. The writer desired to give the records of the shaft and the other two wells belonging to Mr. Harper, in order to bring out the upper disconformity, but did not succeed in obtaining these three records. The sites of all of the wells were located by Mr. John Stout of South Webster, to whom the writer is under special obligation.

Section of the Adam Brandt Well.

	Ft.	In.	Ft.	In.
[Pennsylvanian]			187	6
Surface	2	0		
Sand rock	7	0		
Slate	1	6		
Sand rock	3	3		
Slate	40	10		
Fire clay	4	0		
Slate	5	6		
Sand rock	29	0		
Slate	3	0		
Sand rock	2	6		
Slate	24	10		
Coal	0	4		
Fire Clay	2	6		
Sandy slate	3	6		
Sand slate	22	2		
Fire clay (good flint)	2	10		
Soft, red mottled fire clay	26	0		
Talc [?]	2	6		
White rock	4	3		
Waverly			46	8
Blue sandy shale	46	8		

This section is an exact copy of the driller's log with the exception of those portions which appear between the brackets [ ], and which have been supplied by the writer. Since no true slates are found in the state, it is, of course, understood that the driller's slate is nothing more or less than the ordinary shale.

Judging from the section as a whole, and especially from the presence of the flint and red fire-clays, it seems more than probable that the

drillers have drawn the Mississippian-Pennsylvanian contact at about the proper horizon. This point of division is also strengthened by the two following sections. The absence of the Maxville is also to be noted, although the well is located within a half mile of the Harper wells where the limestone is rather thick.

Section of the Harper Well just above the shaft.

	Ft.	In.	Ft.	In.
[Pennsylvanian]			164	5
Surface	10	0		
Sand rock	10	0		
Black slate	1	0		
Coal	0	4		
Black slate	1	6		
Grayish blue slate	12	0		
Sand rock	1	0		
Fire clay	6	9		
Black slate	1	6		
Gray slate	1	6		
Fire clay	2	0		
Black slate	1	0		
Gray slate	2	0		
Black slate	1	6		
Diamion [?] coal	1	0		
Sand rock	1	0		
Sand rock	8	0		
Black slate	4	0		
Sand rock	31	0		
Blue sand rock	4	0		
Black slate	16	0		
Coal No. 2	1	0		
Bed rock	6	0		
Conglomerate rock	1	6		
Bone shale	36	0		
Green clay	1	6		
Iron ore	1	4		
[Maxville limestone]			42	2
Limestone	3	0		
Green clay	1	0		
Limestone	5	0		
Dark sandy clay	3	6		
Limestone	4	0		
Clay	0	6		
Limestone	15	0		
Clay	0	8		
Limestone	8	0		
Clay	0	6		
Dark limestone	1	0		
Drill stopped.				

In this section, as in the last one, the zones marked slate are intervals of shale, and the portions within the brackets have likewise been supplied. Otherwise the section has not been changed.

There are a number of reasons for referring the limestone to the Mississippian series and hence drawing the Pennsylvanian-Mississippian line of contact at the place indicated. A green fire-clay, similar to the one in the well, is found just above the Maxville and in the basal portion of the Sharon in quite widely distributed areas in this portion of the state. Then, too, the iron ore lying directly upon the limestone recalls a like condition of the Maxville at so many places throughout its area of outcrop. And last, but not least, is the fauna itself which is of undoubted Mississippian age.

A careful search was made in the material of the shaft dump for organic remains. The limestone layers themselves seemed to be very poor in fossils, but the soft argillaceous shales between yielded quite a number. Although some force had distorted practically all of these, yet the following forms were identified, of which *Rhombopora armata*, *Eumetria marcyi*, and *Cleiothyris hirsuta* have been found only at this place.

1. Blastoid unidentified
2. Crinoids unidentified
3. Septopora rectistyla Whitfield
4. Fenestella serratula Ulrich
5. Rhombopora armata Ulrich
6. Derbya crassa Meek and Worthen
7. Productus cestriensis ? Worthen (badly crushed)
8. Spirifer keokuk Hall
9. Seminula subquadrata ? Hall (badly crushed)
10. Eumetria marcyi Shumard
11. Cleiothyris hirsuta Hall
12. Allorisma maxvillensis ? Whitfield (badly crushed)
13. Bellerophon sp.

Another important feature is the structure of the stratum itself. If the well record be correct, or approximately so, it will be seen that the lower half is rather massive, whereas the upper half is more thinly bedded with clayey or shaly partings. Furthermore, the presence of the shale-nodular zone is strongly suggested by the rather large number of fossils found in the clayey shales of the shaft dump. The positive identification of this zone would definitely reveal the development of the lower and upper zones of the formation in this, the southern, as well as in the Northern Area. Since a study of the shaft itself is impossible because it is filled with water, the determination of these points is not possible, and the lack of this shaft section is the more regrettable.

Mr. H. L. Harper worked in this shaft, and although he did not keep any records yet he was able to give considerable information from memory. The shaft penetrated the limestone for seventeen feet, and

the whole of this interval was made up of layers, varying from eighteen to thirty-six inches in thickness, with shaly partings, varying in turn from one to three inches. The layers were horizontal and even, except the top one. The lower surface of this one was even, but the upper surface was wavy. The iron ore varied from fourteen to twenty-four inches. It was wavy also and conformed to the upper surface of the limestone. Furthermore, the shaft was sunken twenty feet lower than was calculated from the nearest well, the first below the shaft, before the limestone was reached. This information further strengthens our belief in the development of the lower and upper zones and in the disconformity at the top, the latter feature of which is so universally present.

Section of the McGugin & Co. Well.

	Ft.	In.	Ft.	In.
[Pennsylvanian]			157	0
Surface	14	6		
Slate	7	6		
Sand rock	3	6		
Slate (sandy)	3	6		
Slate	2	0		
Sand rock	1	0		
Slate	10	6		
Coal	0	4		
Fire clay	2	0		
Sandy slate	12	8		
Slate	2	0		
Sand rock	36	6		
Slate	25	0		
Fire clay	4	0		
Sandy slate	1	6		
Slate	7	6		
Coal	0	2		
Fire clay	1	0		
Slate	3	4		
Sandy slate	17	6		
Clay	1	0		
[Maxville limestone]			43	0
Marble	3	2		
Clay	0	6		
Marble	5	11		
Clay	3	5		
Marble	3	9		
Clay	0	8		
Marble	15	4		
Clay	1	8		
Marble	8	7		

In this well, as in the others, the driller's slate is not slate at all, but shale. The marble is, undoubtedly, the limestone of the Harper well. Pieces of the limestone which came from the shaft, it will be

recalled, showed some evidence of slight changes, but not sufficiently great to produce a marble. The geologic divisions, on the other hand, may be charged against the writer.

Attention is especially called to the great similarity of the layers of limestone in this well and in the Harper well. As in that well, the lower half is apparently a very thick bedded limestone. The upper half, on the other hand, consists of thinner beds and more intervals of shale.

Professor Orton, in his description of the limestones of Lawrence County, says: "This limestone (Lower Mercer), or the Maxville, was encountered at Olive Furnace in a bore hole, two hundred feet beneath the surface. The core removed was almost white, exceedingly dense, and a very pure carbonate of lime. The thickness was reported about twelve feet."[1] It seems more than probable that the limestone to which Professor Orton referred is the Maxville, although the well is not definitely located. Neither does the depth nor the thickness agree with the limestone in the McGugin or Harper wells. On the other hand, the color, texture, and purity agree very closely with the Maxville, and, on the whole, the evidence points toward the Maxville.

EXPOSURES ALONG THE OHIO RIVER.

By referring to the geologic maps of Ohio and Kentucky, the Mississippian-Pennsylvanian line is seen to extend along both sides of the Ohio River valley for a number of miles above Portsmouth. Formerly the river washed the base of a number of high hills in this vicinity and removed the talus to such an extent that the rocks are frequently exposed practically to their tops. These hills are excellent places for the study of the strata both above and below the line of contact and a number of them have been examined.

At the base of such a hill, between Sciotoville and Portsmouth, is the plant and quarry of the Peebles Paving Brick Company. The Cuyahoga shales are utilized to a height of over one hundred feet, and some 260 feet above the top of the quarry is the upper limit of the Waverly series. The Maxville limestone is wanting, and the Pottsville rests directly upon the Logan.

Another similar hill just west of Sciotoville contains a number of good exposures. According to the barometer, the base of the Pennsylvanian is 200 to 240 feet above the river. The following partial section at the line of contact was made at a point about opposite the Norfolk and Western Railway depot. The section shows the Maxville to be absent at this place also.

[1]Orton, Edward Jr. The Limestone Resources and the Lime Industry in Ohio, *Geol. Surv. Ohio*, Bull. 4, p. 85, 1906.

Section of the hill at the lower end of Sciotoville.

	Ft.	In.	Ft.	In.
Sharon conglomerate			1	3
A^4—Coarse-grained gray sandstone, with plant remains. Although the exposure is only 10 feet long the lower surface is seen to be wavy. In this same member is developed a valuable flint fire-clay, which has been extensively worked in this vicinity.				
Disconformity.				
Logan formation			12	6
A^3—Thin-bedded to shaly, fine-grained, light buff sandstone. The layers are about uniform in thickness and horizontal.	2	6		
A^2—Interval covered	3	0		
A^1—Medium to thin-bedded, fine-grained sandstone with *Taonurus* at the top.	7	0		

It has just been shown that the Mississippian limestone is absent in those Ohio River hills at and below Sciotoville. Furthermore, it is not known to be present in any of them on the Ohio side of the valley. The limestone has escaped complete removal by pre-Pottsville erosion, however, on the Kentucky side farther up the river, in the vicinity of Limeville (Tongs P. O.).

Opposite the depot is the residence of John H. Merrill. Back of the residence is a very steep and high hill, in which the Maxville is exposed near the summit. Here the following important section was made.

Section of the John H. Merrill Hill.

	Ft.	In.	Ft.	In.
Undetermined			37	6
B^{18}—Interval covered	9	6		
B^{17}—Horizon from which iron ore was dug.				
B^{16}—Interval covered except a few feet of arenaceous shale at the base	28	0		
Sharon member			19	6
B^{15}—Coarse-grained, medium- to thin-bedded, gray sandstones with zones of iron ore and of soft arenaceous shales. The shales weather back and form shelves of the sandstones. Plant remains	2	4		
B^{14}—A zone of soft, arenaceous shale, which weathers back leaving plant remains suspended from the sandstone layer above	0	6		
B^{13}—Massive layer of medium-grained, gray sandstone, containing plant remains.	7	5		

	Ft.	In.	Ft.	In.
B^{12}—Light gray sandstone with some lime in it.	1	0±		
B^{11}—Sandstone in which iron ore and chert nodules occur	0	9		
B^{10}—Green, flint fire-clay which is filled with small concretions of iron ore and which also contains larger nodules of the same material. Decidedly cal-calcareous in places. The contact with the sandstone above and the brecciated layer below is wavy. Varies from 5½ feet to 8 feet	5	6		
B^{9}—Loosely consolidated breccia in which the majority of the pieces are limestone and small. Here and there the breccia contains some iron ore at the top. In some places there is a trace of a green, argillaceous or calcareous shale or fire-clay in a wavy zone at the base. In other places the fire-clay breaks up into branching beds. The whole zone varies from 2 feet to practically zero. It was first placed in the Maxville, but it is probably the Maxville limestone worked over and deposited along with the green fire-clay. If the contact be either at the base or at the top of this zone, it is nevertheless one of disconformity. Because of the cementing of this zone to the top of the layer (B^{8}) beneath and the gradual transition into the fire-clay (B^{10}) above, the contact is not sharply defined. However, where this zone is practically wanting the green fire-clay rests disconformably and sharply upon the hard subjacent layer or upon 2 or 3 inches of less completely consolidated nodular limestone which in turn rests upon the said subjacent layer (B^{8}). In these cases (i. e., where B^{9} is wanting) the upper surface of the subjacent layer (B^{8}) is very wavy and has nearly vertical grooves, resembling slicken-sides. From about 0 to....	2	0		
Disconformity.				
The Maxville limestone, total thickness			45	9
B^{8}—Layer of gray or dove-colored, compact, hard, pure limestone with calcite scattered throughout. It is slightly brecciated at the top, the angular				

	Ft.	In.	Ft.	In.
pieces being of a medium size and calcareous. Near the up stream end of the exposure pre-Pottsville erosion completely removed the layer so that in places it has no thickness, whereas in others it reaches	2	9		
B^7—Zone of shales alternating with limestone nodules or layers of limestone nodules. In places the zone is finely brecciated. Especially is this true at the base, where the pieces in many places adhere to the top of the underlying layer. The unevenness of the base of the superjacent layer is also partly due to this tendency on the part of the angular pieces to adhere. The zone as a whole is not so firmly consolidated and weathers back more rapidly than the rest of the stratum. The erosion which in places removed the superjacent layer (B^8) also extended into the upper part of this one, thus giving from 2 feet and 9 inches to 3 feet of erosion in a horizontal distance of 6 feet. The zone, therefore, varies from 2 feet to	0	6		
B^6—Practically all massive, pure, gray or dove-colored limestone with calcite crystals scattered through it. However, in some places, there is a slightly developed zone of shales and nodular layers at the top and also more of a tendency to split into layers. Furthermore, the top is finely brecciated in places, and a portion near the top, in others	16	0		
B^5—Massive limestone without definite bedding-planes. There are, however, irregular horizons along which the limestone may separate more readily, and a part of it when subjected to weathering tends to split up in a manner suggesting cross-bedding. It is mostly an impure, sandy-gray limestone. The sand is composed of small white quartz grains. The stone also apparently contains a few small grains of limestone and some calcite crystals. The very base is shown for a horizontal distance of only six inches, so that it cannot be determined whether or not it rests disconformably upon the Waverly	26	6		

	Ft.	In.	Ft.	In.
Waverly series			241	2
B^4—Soft, argillaceous blue shale	0	5		
B^3—Layer of sandstone in which nodules of impure limestone occur	0	9		
B^2—Massive to thin-bedded, fine-grained buff sandstone. Slightly covered in places			153	0
B^1—Covered to the level of the Chesapeake & Ohio Railway tracks below the depot	87	0		

In the section just given, attention should be called to the massiveness of the stone and to the uncommon and poorly developed bedding-planes. These features, of course, suggest the lower half of the Maxville. However, no fossils are found to assist in this correlation. On the other hand, the cross-bedded appearance, which a portion of the stratum assumes when subjected to weathering, and the presence of sand are features very much like those of the limestone as exposed at Carter, and especially at Carter's Caves, Kentucky. These latter conditions make the stone quite different from the lower zone of the Northern Area and renders correlation with it decidedly uncertain.

The limestone was formerly quarried on the Josiah G. Merrill (now V. E. Thompson) property, about half a mile below Limeville. These quarries are located a short distance up one of the small tributary valleys. Although the quarries have filled up to a considerable extent the following section is still available.

Section of the Josiah G. Merrill Quarry.

	Ft.	In.	Ft.	In.
Pottsville formation			3	1
C^{13}—Green fire-clay, somewhat calcareous	1	6		
C^{12}—Nodular-like pieces of limestone, breccia, and green fire-clay, all of which gradually pass into the green fire-clay above. Probably Maxville limestone worked over and deposited with the green fire-clay	1	7±		
Maxville limestone			15	3
C^{11}—More indurated limestone, which in the lower end of the quarry becomes more compact and pure	0	9		
C^{10}—Shales alternating with nodular and brecciated limestone	1	0±		
C^9—Layer of compact, pure, dove-colored limestone; the nodular and brecciated mass clinging to its upper and lower surfaces gives it an uneven appearance	1	10		

	Ft.	In.	Ft.	In.
C^8—Shales alternating with thin nodular layers of limestone, some of which are brecciated. The shales in the upper part are dark	4	0		
C^7—Layer of compact, pure, dove-colored limestone, which may break up into a number of thin layers. The upper surface is brecciated..............	1	7		
C^6—Shaly parting........................	0	1±		
C^5—Layer of compact, pure, dove-colored limestone, which may break up into two layers	0	9		
C^4—Shales, nodular shales and thin-bedded limestone, the latter of which is finely brecciated. In places the lower foot is hard and forms a part of the next lower layer......................	1	3±		
C^3—Massive layer of compact, dove-colored limestone with a little calcite. Bedding-plane between this and the next lower layer is not conspicuous	2	0		
C^2—Massive layer of compact, dove-colored limestone with a little calcite. Slightly brecciated in places at the top ...	2	0		
Undetermined			7	4
C^1—Covered to the present base of the quarry. Below are massive blocks of coarse, sandy and brecciated limestone. Still farther down, the buff, fine-grained, Logan sandstones with *Taonurus* are seen for a long distance..........				

The limestone of this section differs from the last in that the stratification is more conspicuous. The layers are thin or medium in thickness and more or less interstratified with shales. These, therefore, suggest the upper half of the Maxville limestone. Notwithstanding Professor Andrews's report to the contrary[1], no fossils have been found in this or any of the other exposures about Limeville. The question of correlation is, therefore, still an open one.

THE AREA BENEATH THE SURFACE.

The Maxville limestone was found in a number of oil or gas wells far within its zone of outcrop. This region was previously defined as the "Area Beneath the Surface" and includes, primarily, portions of Monroe and Washington counties. The area was quite fully discussed by Dr. Bownocker in his "Bulletin on Oil and Gas," which has

[1]Andrews, E B. Supplemental Report on Perry County and Portions of Hocking and Athens Counties. *Geol. Surv. Ohio*, Vol. III, pp. 817, 818. 1878.

already been abstracted, and since no more work has been done in this field further discussion is unnecessary.

THE FOSSILIFEROUS BLOCKS IN THE SHARON CONGLOMERATE.

The study of the basal conglomerate in Licking County and in the Cuyahoga Gorge and at Boston Ledges in Summit County revealed the presence of fossiliferous blocks. The blocks are flat and somewhat angular, and differ markedly from the rounded quartz pebbles, which constitute the mass of the stratum. If they were originally limestone—and they probably were—the lime has been replaced by silica in nearly every case. Unfortunately the fossils are in the form of either internal or external molds and very poorly preserved, so that specific identification is practically impossible. The Bryozoa and a species of Productus could be Maxville forms. On the other hand, a specimen of a Brachiopod and one of a Pelecypod differ from any of the Maxville fossils. The imperfect preservation of these fossils, then, does not permit of a definite determination of the horizon whence these blocks came.

SUMMARY.

The plane of contact between the Sharon conglomerate and the Maxville limestone cuts across layer after layer of the limestone in many places throughout the whole area of outcrops whereas in many other nearby ones the Sharon rests directly upon the Logan formation. The upper surface of the limestone is thus very uneven, and is the result of erosion to which the stratum was subjected after it had been raised above the waters of the sea and before it was again submerged to receive the deposits of the Sharon. This line of contact, therefore, represents a long period of time—a gap or hiatus—during which there was not only a lack of deposition, but also a very slow removal of considerable material by erosion as well as the slow movements of elevation and depression. This structure is called a disconformity or, in other words, an unconformity between parallel beds, due to erosion.

This erosion (pre-Pottsville) removed all of the Maxville stratum in many places, whereas in many other adjacent ones a greater or less amount of the limestone escaped complete destruction, so that the stratum is now found principally in isolated patches. This condition has at times been attributed to deposition originally in isolated basins, but which in fact is due to pre-Pottsville erosion. The Maxville limestone was at first undoubtedly a continuous deposit, and was later separated into patches by erosion before the deposition of the Sharon.

Along the belt of outcrops extending from a point near Zanesville to the Ohio River near Wheelersburg, and also along the line of inliers just to the east of this belt, these patches of limestone are relatively

large and abundant from the place near Zanesville to Logan, completely wanting from the latter to Hamden, and exceedingly small and widely separated from the latter in turn to the Ohio River. This gives us three natural divisions, or areas, which have for convenience been designated, respectively, the Northern Area, the Central Area and the Southern Area.

In the Northern Area, along Jonathan Creek and Kents Run, th Maxville limestone is divided into a lower and an upper half by a thin zone near the middle of the stratum. This thin zone, the shale-nodular zone of the report, is made up of small nodules or nodular-like layers of limestone, which alternate with shales, and both of which are very fossiliferous. The lower zone consists of a massive, clayey limestone, the bedding planes of which are irregular and very indistinct. In the upper zone the stratification is the conspicuous feature, because the shaly partings found between the thin or medium layers of limestone are commonly weathered away, thus permitting each layer to project apparently independently from the face of the cliff. This zone in many places is fairly fossiliferous, whereas the lower one is generally but sparingly so.

At nearly every place in the Northern Area where the lower contact of the Maxville is exposed, pre-Pottsville erosion has removed all or nearly all of the upper zone, so that the complete thickness of the formation is difficult to obtain. The shale-nodular zone enables one, however, to trace other zones from place to place, and by combining the measurements of these the thickness of the lower and upper halves is secured. The thickness of the lower half was found to be a little greater than twenty-five feet, and that of the shale-nodular zone to average about three feet. The maximum thicknesses of the upper zone is at a point opposite the Fultonham depot and at one nearly a mile below, where this half is, respectively, about fifteen and twenty-two feet. This gives us a thickness of nearly forty-three and fifty feet for the stratum—the maximum thickness in the Northern Area, and one which agrees very closely with that of records of nearby wells. But it must not be understood that this is necessarily the thickness of the complete original formation at either of these places, because in each one the limestone was overlain by soil; and furthermore, if either of these be the upper contact, it is more than probable that at least some of the limestone has been swept away by pre-Pottsville erosion.

Collections of fossils from the limestone at Cut No. 4 and at the Kroft Bridge in the Northern Area and at the Harper Shaft in the Southern Area have raised the number of species of the Maxville fauna from twenty-four to thirty-six. The new forms are:

1. Fenestella serratula Ulrich
2. Rhombopora armata Ulrich
3. Eumetria marcyi Shumard
4. Cleiothyris hirsuta Hall

5. Cypricardella oblonga Hall
6. Dentalium illinoiense Worthen
7. Bulimorpha canaliculata Hall
8. Orthonychia acutirostre Hall
9. Strophostylus carleyana Hall
10. Murchisonia vermicula Hall
11. Orthoceras randolphense Worthen
12. Orthoceras okawense ? Worthen

Of these the 1st, 3d, 4th, 5th, 7th, 8th, 9th and 10th belong to the Spergen Hill (Salem) fauna, which recurs in the Ste. Genevieve limestone and again in the Tribune limestone.

The lower contact of the Maxville limestone is not shown at nearly so many places as is the upper one, but wherever exposed it furnishes an interesting problem for study. Since the lower part of the limestone is decidedly argillaceous in Cuts No. 3 and No. 4, and since there is seemingly no break between this impure limestone on the one hand and the sandstones and shales of the Logan on the other, the line of contact has to be somewhat arbitrarily drawn. It seems probable that the clay and fine sand which were derived from the Logan were more or less worked over and into the basal layers of the Maxville. At Opera Bridge, on Kents Run, the line of contact is much sharper and is slightly wavy. The upper surface of the subjacent shales is decidedly uneven in the Jockey Hollow exposures, and furthermore the joints in the upper part of these shales are filled with the same kind of material as that which forms the coarse arenaceous limestone of the basal layer of the Maxville. At the last place, then, it is quite obvious that the uneven surface upon which the Maxville rests represents at least a plain of contemporaneous erosion, and when the lower layers of the limestone are studied it seems more than probable that the structure is a disconformity.

A thin zone in the basal portion of the Maxville at Jockey Hollow and near Redington in the Northern Area, and more or less of the entire formation at Hamden (and certain zones at Limeville) in the Southern Area, are decidedly brecciated. Many of the angular pieces are limestone, much purer, harder and darker than the coarse, sandy material which constitutes the mass of the breccia, and, for that matter, darker than any of the Maxville. The origin of these angular limestone pieces could not have been distant, or they would have become rounded in transportation, and if near, then Ohio must have had a Mississippian limestone other than and older than the Maxville, of which they alone are the representatives.

The Sharon conglomerate in Licking and Summit counties contains a few rather large and somewhat flat and angular blocks, which are fossiliferous, and which were supposed to have their origin in the Maxville limestone, although the composition of practically all of them is silica rather than calcium carbonate. This may have been their origin, but it cannot be definitely so stated, since the fossils are so poorly preserved that specific identification is practically impossible.

CHAPTER III.

CORRELATION.

INTRODUCTORY STATEMENT.

A number of things contribute to the difficulty of the problem of Maxville correlation. With the exception of a single Pelecypod mold which was found in the section above the Baltimore & Ohio Southwestern Railroad bridge at Hamden, and the fauna which was collected in the Harper Shaft, no fossils were found in the stratum in the Southern Area. In other words, with the exception of the two places just mentioned, no fossils were found south of Smith Chapel at Logan, the southernmost point of the Northern Area, so that the fossiliferous limestone of the latter area is separated from the fossiliferous limestone of northern Kentucky not only by the wide gap of the Central Area, where no limestone is preserved at all, but also by the practically barren limestone of the Southern Area. Of the fossils that are found along the zone of the outcrop (i. e., in the Northern Area) a part of the abundant ones belong to the Salem (Spergen Hill) fauna, which recurs in the Ste. Genevieve limestone and again in the Tribune limestone, and the remaining part of the abundant ones belong to the Ste. Genevieve and Tribune limestones. The abundant fossils are, in themselves, therefore, not completely diagnostic. The stratigraphic correlation is further retarded by the absence of good exposures to the south. The outcrops of Mississippian limestone of East-Central Kentucky seldom show both the lower and upper contacts in the same section. Furthermore, the conspicuous zones are so frequently covered that the tracing of a zone or of zones from place to place is not always satisfactorily accomplished. But the chief factor in this difficult problem is the lack of detailed information of the typical Mississippi area itself. The horizon from which the described fossils came has not always been correctly differentiated, but, on the other hand, has in some cases been referred to a lower formation and in other cases to a higher one. With these difficulties ever in mind a few statements will be made about correlation.

CORRELATION WITH MISSISSIPPIAN FORMATIONS OF EAST-CENTRAL KENTUCKY.

In working out the Mississippian stratigraphy of East-Central Kentucky, under the auspices of the Kentucky Geological Survey, and in company with Dr. Foerste, it soon became evident that the Waverly terrane, especially the lower half, became thinner and thinner

toward the south. In other words, the apex of the thinning formations of the Waverly lies to the south of the state of Ohio. On the other hand, outcrops of Mississippian limestones seemed to be thick in some places and not so thick in others, but on the whole, they seemed to thicken to the south. As there had been an apex to the thinning formations of the Waverly terrane and probably also to the declining number of its formations, so also it was inferred was there a like apex to the limestones. But in the latter case the apex was toward the north, the Ohio area.

That the St. Louis sea at least approached the Ohio area is shown by a number of outcrops of limestone of this age in East-Central Kentucky. The stratum appears in the exposure at Old Landing, below Beattyville, in Lee County, as revealed by the presence of *Lithostrotion? canadense.* The lower half of St. Louis is found in the highway one mile north of Rothwell in Menefee County, as determined by *Lithostrotion? canadense* and *Lithostrotion? proliferum appearing together* near the middle of an exposure of seventy feet of limestone. *Lithostrotion? canadense* shows the presence of the stratum at the "Y" one mile below Blackwater in Morgan County. The most northern place where the coral reveals the presence of the St. Louis is at the Pumping Station at Olive Hill in Carter County. About fifteen feet above the unconformable base, at this place, are small chert nodules which contain fragments of *Lithostrotion? canadense.*

A green or red clay, which resembles a fire-clay, appears in a number of sections. In the Blackwater section, about fifteen feet above the horizon of *Lithostrotion,* are two feet and seven inches of green clay. In the Highland Stone Company's Quarry, a half-mile east of the Pumping Station at Olive Hill, some fifty feet above the base of the limestone, are three inches of green clay with angular pieces of limestone. A nine-inch horizon of red clay, which turns green on weathering, is found about six feet above the base of the limestone at Carter in Carter County. At the very base of the limestone in Deep Cut on the Lewis-Carter county line are nearly ten feet of red clay. Whether or not the clay which appears at these places is one and the same stratum is not known. If it be the same, then the lower portion of the limestone series disappears at Deep Cut, and, furthermore, this portion represents either the whole or a portion of the St. Louis limestone.

On the other hand, there are certain features which suggest St. Louis age for the whole of the Mississippian limestone as exposed at certain places in the Southern Area and for a small portion of the base of the limestone as exposed in a few places in the Northern Area. The St. Louis limestone is brecciated at Rothwell and at Olive Hill, Kentucky, and, according to Weller, brecciated beds are very characteristic of the St. Louis in Illinois. Furthermore, according to the same author, fossils are usually rare in the St. Louis, and occasionally arenaceous material

is met with in the stratum. In the Fluorspar district of Western Kentucky and Southern Illinois the formation is highly arenaceous, according to Ulrich. At Limeville (John H. Merrill Hill), Kentucky, and at Hamden, Ohio, the two limits of the Southern Area, the limestone is more or less brecciated, is barren of fossils, and contains much arenaceous material. Furthermore, upon exposure to the elements, it presents a cross-bedded appearance. A thin zone at the base of the formation near Rushville (Jockey Hollow) and near Redington in the Northern Area is also decidedly arenaceous and brecciated, and differs markedly from the rest of the stratum in this area. Of course, these features are in no wise conclusive of the St. Louis age of the whole stratum at these places in the Southern Area or of the thin lower portion of the limestone at the two places in the Northern Area, but since the St. Louis is known to be developed as far north as Olive Hill, Kentucky, the suggestion of this age should ever be borne in mind.

Whether the line of outcrop of the St. Louis limestone does or does not enter the state of Ohio is not definitely known, but the approach of this line toward the state, as proven by the presence of *Lithostrotion? canadense,* has, nevertheless, a very important bearing on the question of Maxville correlation. The St. Louis was shown to be developed at least as far north as Olive Hill, and furthermore, the stratum appears at the very base of the limestone series. Therefore, it seems more than probable that the Maxville limestone is no older than St. Louis in age, and this conclusion, in turn, tends to eliminate the possibility of a Salem (Spergen Hill) age of the Maxville fauna, and to suggest instead either Ste. Genevieve or Tribune age, since the Salem (Spergen Hill) fauna recurs in these limestones.

CORRELATION WITH MISSISSIPPIAN FORMATIONS OF THE WEST.

The correlation of the Maxville limestone of Ohio, or, more strictly speaking, the correlation of the Maxville of the Northern Area of the state, with the formations of the West (i. e., the Central West) must, in the main, be made on paleontologic evidence. How unsatisfactory these results will be may be judged from the rather chaotic condition of the literature on stratigraphy and especially of that on the geologic distribution of the fossils of that region. However, the refined work of Weller and Ulrich has made something possible along this line.

Before going farther into the subject of correlation it becomes necessary to adopt a table of formations as a basis. The following one is by Ulrich and is copied from page 24 of Professional Paper No. 36 of the United States Geological Survey for this purpose, even though Weller states that "it must be somewhat modified to represent the true relations of Mississippian beds of Illinois."[1]

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[1]Weller, Stuart. The Geological Map of Illinois. *Ill. State Geol. Surv.,* Bull. 6, p. 23. 1907.

Table of Formations in the Kentucky-Illinois Fluorite District.

				Names of Formations and Members Used in this Work.		Synonyms and Equivalent Formations in the Mississippi and Lower Ohio Valleys.	
Carboniferous.	Pennsylvanian.		Potts-ville group.	Mansfield sandstone.		Mansfield sandstone of Indiana. Coal Measures conglomerate of western Kentucky.	
	Mississippian.	Tennesseean.	Chester group.	Kaskaskia limestone.	Birdsville formation.	Kaskaskia limestone of Hall. Chester limestone of authors. Huron formation of recent Indiana reports is same as Birdsville formation.	
					Tribune limestone.		
				Cypress sandstone.		Aux Vases sandstone of Keyes. Probably also Big Clifty sandstone of Norwood.	
				Ste. Genevieve limestone.	Ohara limestone. Rosiclare sandstone. Fredonia oolitic limestone.	Two upper members referred to as lower Chester by Worthen and Engelmann. Entire formation referred to as St. Louis by Norwood.	
			Meramec group.	St. Louis limestone.		St. Louis limestone of most authors, but not of Engelmann, Shumard and Swallow, who do not include two lower formations in the St. Louis limestone. The two upper formations equal, respectively, the Mitchell limestone and the Bedford oolitic limestone of recent Indiana reports.	
				Spergen limestone.			
				Warsaw formation—lacking.			
		Waverlyan.	Osage group.	Tullahoma formation.		Keokuk limestone. Burlington limestone.	Harrodsburg limestone (typical) and Knobstone of Indiana.
			Kinder-hook group.			Various formations of the Kinderhook group.	
Devonian.			Che-mung group.	Ohio shale.		New Albany shale of Indiana reports. Chattanooga shale. Grassy Creek shale of Keyes.	

In order to bring out more clearly the fossil evidence of the age of the Maxville limestone the geologic distribution of the species is shown, as far as possible, in the following table. Since the stratigraphy of the Harper Shaft is not known in detail and since this is the only place in the Southern Area where fossils have been collected from the limestone, the three species, *Rhombopora armata, Eumetria marcyi* and *Cleiothyris hirsuta,* which are found only at this place, are eliminated from the following discussion and have hence been placed in brackets [ ]. The species have been arranged in a number of columns, those which are found only in the Maxville have been placed in one. Those species the geologic range of which has actually been determined by Ulrich have been placed in one or more of the five columns used by him. Those species which the older literature refers to either the Chester (Kaskaskia) or St. Louis have been placed in their respective columns, whereas those species, the geological range of which is very great or the horizons of which are not carefully designated, have been placed in a single column, called the indeterminate.

	List of Species.	Terranes								
		After Ulrich					Authors			
		Birdsville or Tribune	Ohara	Fredonia	St. Louis	Spergen	Kaskaskia or Chester	St. Louis	Maxville only.	Indeterminate
1	Zaphrentis cliffordana									x
2	Pentremites elegans									x
3	Cyathocrinus maxvillensis								x	
4	Septopora rectistyla								x	
5	Fenestella serratula	x	x	x	x	x				
6	Rhombopora armata						[x]			
7	Derbya crassa									x
8	Productus pileiformis									x
9	Productus cestriensis	x	x							
10	Martinia contracta						x			
11	Spirifer keokuk									x
12	Dielasma turgida	x	x	x	x	x				
13	Seminula subquadrata	x	x	x						
14	Eumetria marcyi									[x]
15	Cleiothyris hirsuta		[x]	[x]		[x]				
16	Schizodus chesterensis						x			
17	Pinna maxvillensis								x	
18	Allorisma andrewsi								x	
19	Allorisma maxvillensis								x	
20	Cypricardella oblonga	x		x		x				
21	Dentalium illinoiense						x			
22	Straparollus similis							x		
23	Holopea newtonensis								x	
24	Bulimorpha melanoides								x	
25	Bulimorpha canaliculata							*x		
26	Sphærodoma subcorpulenta								x	
27	Naticopsis ? ziczac								x	
28	Bellerophon alternodosus								x	
29	Bellerophon sublævis	?		x		x				
30	Orthonychia acutirostre	x		x		x				
31	Strophostylus carleyana							*x		
32	Murchisonia vermicula							*x		
33	Endolobus spectabilis						x			
34	Nautilus pauper								x	
35	Orthoceras randolphense						x			
36	Orthoceras okawense?						x			
	Total	6	4	6	2	5	6	4	11	5

From the above table it will be seen that after deducting the three species which are found only in the Southern Area (Harper Shaft), thirty-three remain for the Northern Area. Of these thirty-three eleven are from the Maxville alone and five are indeterminate. Of the ten the

geologic position of which has been fixed by the older literature, six are of Chester age and four of St. Louis, but of the four St. Louis ones, the three marked with an asterisk * were originally described from Salem (Spergen Hill) material and hence may have the range of the other species of this fauna. Of the seven the geologic distribution of which has been definitely fixed by Ulrich, two range without interruption from the Salem (Spergen) or earlier to the Tribune-Birdsville; three belong to the recurring fauna of the Salem (Spergen), Fredonia, and Tribune; one appears first in the Fredonia and one appears first in the Ohara.

In forming a just estimate, however, of the faunal evidence it is necessary to take into consideration the relative abundance of the species as well as the relative number of the species. The two most abundant species, *Productus cestriensis* and *Seminula subquadrata,* range upward from the Ohara and Fredonia respectively. Of the two next most abundant, *Bellerophon sublaevis* belongs to the recurring fauna of the Salem (Spergen), Fredonia and Tribune, whereas *Straparollus similis* is confined to the "St. Louis," but this old "St. Louis" may have included anything from the base of the Warsaw to the top of the Fredonia or higher.

The paleontologic evidence as to the age of the Maxville limestone of the Northern Area seems to be about equally divided between the Fredonia and Ohara members of the Ste. Genevieve formation, with the odds in favor of the Ohara.[1]

If the sections of the Ste. Genevieve limestone published by Ulrich on pages 41 to 43 of Professional Paper No. 36 be carefully studied it will be seen that the Maxville limestone of the Northern Area agrees more closely with the Ohara than with any of the other members of this formation. The fossiliferous shale-nodular zone of the Maxville compares very favorably with the fossiliferous shales and thin seams of limestone in zone 5 of Ulrich's section of the Ohara. The beds above zone 5 consist chiefly of thin-bedded limestone and interbedded shales, whereas those beneath are, as a rule, more massive, thus agreeing respectively with the upper and lower zones of the Maxville. Then, too, *Productus cestriensis* is one of the most abundant fossils.

With the paleontologic and stratigraphic suggestions pointing as just indicated and with the unconformity between the Warsaw and

[1]In communications to the writer, Dr. Weller has expressed his belief in the Ste. Genevieve age of the Maxville, and Dr. Foerste in the Ohara member of the Ste. Genevieve formation.

For the benefit of those who have not read the bibliographic portion of this paper, and hence also in justice to the earlier workers, it should be stated that Andrews (1870) from the first suspected the Maxville of being Chester in age, that Meek, in a letter to Andrews (1871) expressed his belief of Chester and possibly also of St. Louis age of the fossils from the Maxville, and that Whitfield (1882), in his descriptions of the fossils from the Maxville, stated that the stratum was the equivalent of the Chester or of the Chester and St. Louis.

Salem (Spergen) and the one between the Ste. Genevieve and Cypress (Weller) in mind the conditions of deposition of the Mississippian strata may be represented graphically as in the following figure (5).

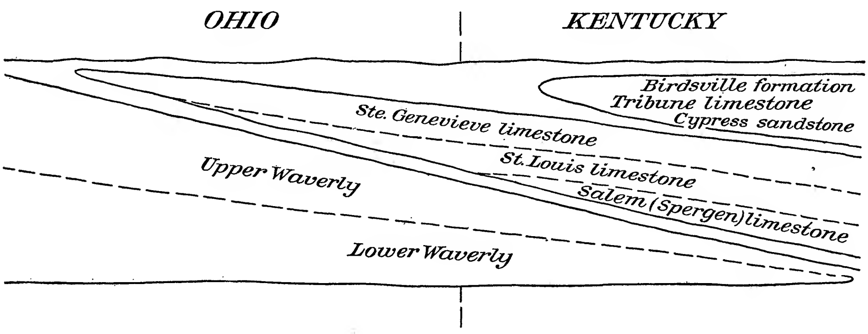

Fig. 5.—A diagrammatic sketch to illustrate the thinning out of a number of Mississippian formations in the Kentucky-Ohio area.

It may be necessary to draw the apex of the St. Louis at Olive Hill, Kentucky, instead of at the place indicated, but, on the whole, the general relationship as represented is probably about correct.

CORRELATION WITH THE MISSISSIPPIAN FORMATIONS OF THE APPALACHIAN REGION.

The Mississippian series of Southern Pennsylvania and adjacent territory is usually divided, in ascending order, into the Pocono, Greenbrier and Mauch Chunk formations. In the bibliographic portion of this paper, however, it was shown that Stevenson (1903) divided the Greenbrier limestone of the United States and Maryland reports into two divisions, a lower, siliceous, non-fossiliferous limestone, and an upper, purer, fossiliferous limestone. Because Weller pronounced the fossils, which Stevenson sent to him from the upper portion of the limestone of Fayette County, Pennsylvania, as practically identical with the Maxville fauna of Ohio, as described by Whitfield in Volume VII of the Ohio reports, Stevenson adopted the term Maxville for this upper division. For the lower portion and for the underlying shales which constitute the lower of the three divisions (according to Stevenson) of the original Mauch Chunk he used the term Tuscumbia. These changes are more clearly shown in the following table:

Usual Divisions.		Stevenson.
Mauch Chunk		Shenango.
Greenbrier	pure	Maxville.
	siliceous, shales	Tuscumbia.
Pocono		Logan.
		————

The lower portion of the Greenbrier limestone, which, according to Stevenson, is siliceous, non-fossiliferous and cross-bedded, is suggestive of the whole of the limestone series as exposed at Limeville (John H. Merrill Hill), Kentucky, and at Hamden, Ohio, and of the lower portion of the limestone as exposed near Rushville and near Redington, Ohio.

Collections of fossils of the Greenbrier limestone, from a number of localities in Garrett County in Western Maryland, have, in the present study, been examined and compared with similar ones from the Maxville of Ohio. The Maryland specimens were collected by Professor Prosser and Dr. Richard B. Rowe, under the auspices of the Maryland Geological Survey, at a number of places from Oakland to the Pennsylvania-Maryland state line beyond Friendsville. The following list includes specimens from all of these localities:

1. Archimedes sp.
2. Derbya crassa Meek and Worthen
3. Productus pileiformis Hall
4. Productus cestriensis Worthen
5. Productus sp.
6. Martinia contracta Meek and Worthen
7. Spirifer keokuk Hall
8. Dielasma turgida Hall
9. Seminula subquadrata Hall
10. Eumetria marcyi Shumard
11. Cleiothyris hirsuta Hall
12. Allorisma maxvillensis Whitfield
13. Straparollus similis ? Meek and Worthen
14. Bellerophon sublævis Hall
15. Bellerophon textilis ? Hall
16. Bellerophon sp.
17. Trilobite pygidium

A glance at the above list reveals a Maxville fauna. The four abundant forms, *Productus cestriensis, Seminula subquadrata, Bellerophon sublævis* and *Straparollus similis,* of the Maxville are represented in this list. *Seminula subquadrata* is also abundant in the Greenbrier and

Productus cestriensis is common. Some of the species vary slightly from the same ones of the Maxville, but not sufficiently so for varietal designation. From a faunal study it is clearly seen that the Greenbrier is the Appalachian equivalent of the Maxville limestone of at least the Northern Area of Ohio.

CHAPTER IV.

ECONOMIC GEOLOGY.

INTRODUCTORY STATEMENT.

In the past the Maxville limestone has been used for a number of different purposes. Before the days of cheap transportation it was burned for lime for local consumption at rather a large number of places, and when the Pennsylvanian iron ores of the southeastern portion of the state were utilized the limestone was used as a flux in the then widely distributed charcoal furnaces. It has also been used to some considerable extent for road metal and to a lesser degree for a building stone.

ROAD METAL.

GENERAL STATEMENT.

Of these uses and others yet to be mentioned, it seems to the writer that that of road metal is by far the most important. If the geological map of Ohio be consulted it will be seen that the line separating the Devonian shales on the one hand from the Devonian limestones and older rocks on the other, passes north and south through Columbus and divides the state roughly into two halves. The rocks of the western half are dominantly limestones, whereas those of the eastern half are dominantly sandstones and shales. Passing east from this dividing line across the wide belts of Devonian shales and Waverly sandstones and shales, one finds no limestone until the Maxville is reached, as a scarp at the border line of, or as an inlier just within the limits of, the Pennsylvanian series. Beyond this only here and there is a limestone stratum found and each one of these is, as a rule, very thin and unimportant. The Maxville is thus seen to constitute about the only limestone of much development within this eastern half of the state.

The superiority of limestone over sandstone and shales in highway or pike construction is too well known to elicit much discussion. Sandstones may be harder and more resistant to the wear of vehicles, but they lack the power of cementation so valuable in the limestones, by means of which the road metal becomes a solid block of concrete, thus making an excellent road.

In thus setting forth the economic importance of the Maxville as a source of road material, it is not to be understood that a great local development in a comparatively few places is urged. This would neces-

sitate other than local consumption and bring the limestone into competition with other railway transported limestones, a result that might prove disastrous financially. On the other hand, it is the firm belief of the writer that the limestone should be quarried at practically every place where its isolated exposures show it to be, and the stone so quarried should be used in the immediate vicinity to construct better roads. The roads would not only be wonderfully improved, but the value of the adjacent lands would be greatly enhanced. The beneficial results would thus be more important and far-reaching than in the case of a great local development of one quarry or of a number of them.

In order to further emphasize the importance of this limestone for local consumption in road making it becomes necessary to briefly review the places of occurrence, and this can probably best be done by counties.

MUSKINGUM COUNTY.

This county is one of the richest so far as distribution of the Maxville limestone is concerned. The limestone is exposed for a number of miles from White Cottage up both Kents Run and Jonathan Creek, and could be quarried at a large number of places along both of these streams. At some places it is somewhat more easily accessible and hence some of these should be mentioned.

At the first covered bridge across Kents Run, above White Cottage, and also on the farm of R. G. Thompson the upper part of the Maxville is exposed along the banks of the stream. A little stone has been taken out and a considerable amount could be quarried with the removal of only a small amount of overburden. Both exposures are also very convenient to the highway.

Within the village of White Cottage itself the limestone is exposed in the bed of both streams. Some stone has been removed here and more is readily accessible. A little prospecting would probably reveal a place where considerable could be quarried with the removal of only a small amount of waste.

Near and within the town of Fultonham (Axline P. O.) the upper portion of the Maxville forms the banks of the streams. The stone was formerly quarried to a considerable extent at the depot. This is one of the best places for the development of quite a large quarry, because the stratum forms a terrace ten or fifteen feet above the stream and is covered with only a small amount of material.

PERRY COUNTY.

Numerous railway cuts in Jonathan Creek gorge above Fultonham expose the Maxville in Muskingum as well as in Perry County. Large amounts of stone could be quarried with some difficulty at these places.

It is, also, not so readily accessible for local consumption as a road metal, since the principal highways do not enter the gorge and the two roads which do cross the stream ascend very steep hills on either side. These locations seem better for development along a different line.

In the highway leading northwest from Redington opposite the residence of J. H. Gordon is an exposure of sixteen feet of Maxville. The exposure is rather poor and the stone does not occur under very favorable quarrying conditions, but it may be possible that enough could be obtained for the roads of the immediate vicinity. The limestone outcrops in the road two and a quarter miles east of Oakthorpe, near the home of Mrs. Alice Baker, and a quarter of a mile southwest it occurs at the very top of the Cover Hill just within Fairfield County. At the latter place seven feet were opened up for road material, and a considerable amount of stone could be quarried here with practically no stripping.

Near the Zanesville and Maysville Pike and the Otterbein United Brethren Church, one mile east of the Fairfield-Perry county line, is the G. W. Folk quarry. A rather large amount of stone has been taken from this place for road metal and the quarry is still open. The stratum occurs so near the summit of the hill that very little overburden needs to be removed, and, furthermore, the areal extent at this point may be considerable. Its occurrence at the top of the hill and its close proximity to the highway make this an important quarry.

One mile south of the Otterbein United Brethren Church, the state road crosses Jockey Hollow at J. S. Shafer's residence, and just below the road some twenty feet of the Maxville are exposed. A little of the limestone was quarried here for road metal. The thickness of the stratum is sufficient to make this one of the important outcrops where a considerable amount of stone could be quarried.

The next exposures of the stratum take us to the type locality, namely Maxville, in the extreme southern portion of the county. The limestone is exposed at various places along Little Monday Creek; a half mile above Maxville, within the village itself, on both sides of the stream a half or three-quarters of a mile below town, and on the west side a mile and a half below. In Lime Kiln Hollow, within the village, it was at an early date quite extensively quarried and burned for lime, and was also used to some extent for furnace flux. On the Hendricks and Howdeshell properties, a half or three-quarters of a mile below town, it was wrought to quite a considerable extent for both flux and lime. A mile and a half below the village it was quarried for lime, and here may be seen the old kiln still standing and the old log store house in a good state of preservation. The stone could be quarried at any of these places, and especially on the Hendricks and Howdeshell properties, with a very reasonable amount of stripping. The limited north and south in connection with the small east and west distribution should

make the preservation of the limestone at this place one of utmost importance. The stone should experience a growing demand as a road metal.

HOCKING COUNTY.

So far as known, the exposures of the Maxville are limited to one locality in Hocking County. These occur just east of Smith Chapel or about two miles east of Logan. The limestone was formerly quarried here and hauled overland to the old furnace located seven or eight miles to the south at Union Furnace. The stone could be quarried with the removal of a reasonable amount of overburden and is readily accessible to the principal thoroughfares of travel.

VINTON COUNTY.

Like those of the preceding county, the outcrops are limited to one vicinity and this is in the extreme southern portion of the county. Twelve to eighteen feet of limestone are exposed along the banks of Little Raccoon Creek just east of Hamden. The top of the exposures forms a terrace so that the amount of stripping would be very small indeed. These exposures constitute another isolated patch of limestone and this preservation of only a limited area should again add to the value of the stone as a source of road metal.

JACKSON COUNTY.

The limestone is also limited to one locality in this county, and this is in Section 24 in Hamilton Township in the southwestern part of the county. It occurs principally on the land of Amos (son of Enoch) Canter. Long ago it was quarried to a considerable extent for furnace flux and more recently for road metal. The isolation of this small area should also add to its value and it should be eagerly sought after as a road metal.

SCIOTO COUNTY.

The limestone occurs in two or three places in Section 24, Harrison Township. It has been worked for furnace flux along the narrow Niner Ridge, but the areas are too small to be important sources of road metal.

RAILWAY BALLAST.

GENERAL STATEMENT.

Railroads are coming more and more to use crushed stone as a ballast, and especially is this true of limestone. A considerable percentage of the enormous amount of Devonian limestones quarried just west of Columbus is used by the Pennsylvania Railroad for ballast. Large quar-

ries in limestone of Mississippian age at Carter and Olive Hill, Carter County, Kentucky, supply the Chesapeake & Ohio Railway with trainload after trainload of ballast. Likewise a quarry in the same horizon just west of Natural Bridge, Kentucky, furnishes a considerable amount to the Lexington & Eastern Railway.

There is no good reason why in Ohio the Maxville limestone, which is of similar age, should not be used for this same purpose. Especially is this the case at the places now to be mentioned. Of course the item of transportation is not so important as it was in the case of the road metal since the railroads handle their own freight, and yet the extra mileage is a factor which should not be overlooked.

PERRY AND MUSKINGUM COUNTIES.

Various exposures of Maxville along Jonathan Creek are exceedingly convenient to the Zanesville & Western Railway. Especially is this true of those in the village of Fultonham, and, to a less degree, in the cuts above town. The Maxville forms the wide structural terraces opposite the depot in Fultonham, and hence the amount of superjacent waste to be removed would be very small. No more favorable site for a quarry of considerable extent could be desired. Since the Maxville is frequently wanting, due to pre-Pottsville erosion, careful drill tests should precede the expenditure of any considerable amount of money for equipment. The cuts above Fultonham offer similar advantages, and they are even more convenient to the railroad; but a considerable amount of stripping would have to be done at these places.

VINTON COUNTY.

The exposures along Little Raccoon Creek just east of Hamden are adjacent to the Baltimore & Ohio Southwestern Railroad. From twelve to eighteen feet of limestone are exposed along the banks of the stream above water level. Since the stratum forms the structural terrace, already mentioned, the amount of overburden to be removed is small. In all cases where an expenditure of much money is necessary for stationary crushers and other equipment, the areal extent of the stratum should be positively ascertained by drilling.

OHIO RIVER VALLEY.

If the writer may be pardoned for crossing the river, the political boundary in this discussion, something will be said about the exposures at Limeville (Tongs P. O.) Kentucky. It was necessary to do this in the stratigraphic study and it seems to fall within the economic province. The stratum occurs near the summit of the hills, about 250 feet above the Chesapeake & Ohio Railway, and is about fifty feet in thickness.

Formerly it was quarried to a considerable extent and burned for lime. From the quarries on the hill the rough stone could be dropped through chutes to a crusher near the base and from this the crushed product could be loaded by gravity into the car and thus reduce the cost of production.

CEMENT STONE.

GENERAL STATEMENT.

In speaking of Dolomite, (Ca, Mg) CO^3, Bleininger says: "As a cement material it is not promising, since it gives rise to two silicates (of lime and magnesia) which have different rates of hydration and which hence interfere with each other in the hardening process, unless the burning took place at a low temperature not over 1000° C."[1]

Orton and Peppel state that: "Limestone, or mixtures of limestone and shale within the following limits of composition, will be found to be very close to the composition desired in a Portland Cement mixture:

	Per cents.
Silica	15–16
Alumina and ferric oxide	6– 7
Calcium carbonate	74–76
Magnesium carbonate	0– 4.5

"The ingredient which we must watch with greatest care is magnesium carbonate. It must not go beyond 4.5 per cent., and the lower it is the better. If the silica and alumina are too high, we can correct this by throwing out a little clay or shale or adding a little high calcium limestone."[2]

The ban thus placed upon magnesian limestones for cement purposes greatly restricts the area of possible production. About three-fourths of the western half—the limestone half—of the state is underlain with Silurian and Devonian limestones, but these are almost exclusively magnesian. Of the limestones of the remaining one-fourth, Orton and Peppel's analyses show that nearly all of the Ordovician limestone is chemically available for cement purposes, that the composition of the thin Clinton (Silurian) is often favorable, and that a small lentil—the Dayton limestone (Silurian)—which lies just above the Clinton is at some places chemically desirable. All three of these, however, outcrop only in the southwestern part of the state, in the Ordovician area, and in a very narrow belt in the Silurian, adjacent to the former. Their location away from the coal fields is an unfavorable factor, and their manner of outcropping is not always the most desirable. The De-

[1]Bleininger, Albert V. The Manufacture of Hydraulic Cements. *Geol. Surv. Ohio*, Bull. 3, p. 38. 1904.

[2]Op. cit. p. 88.

vonian limestones, on the average, are not chemically adaptable to cement manufacture, the most favorable place being Columbus, and the desirability of the stone at this place has been questioned. The great restrictions thus placed upon the otherwise large limestone areas of the western half of the state by their chemical composition and the location of those chemically desirable beyond the coal fields enhance the value of the limestones of Mississippian and Pennsylvanian age. The location of the Maxville adjacent to, and mostly within, the area of coal bearing rocks is thus seen to be a very important factor.

FULTONHAM AND WHITE COTTAGE.

An analysis was made of samples of the Maxville limestone from a number of different places. The most important of these analyses are of the limestone from Fultonham and White Cottage, since the samples include stone from a number of consecutive feet at the top of the stratum. These two analyses will now be given.

Analysis of the upper twelve feet of the Maxville limestone at Fultonham.

Silica	2.80
Alumina	1.16
Ferric oxide	
Carbonate of calcium	92.80
Carbonate of magnesium	2.13
Total	98.89

Analysis of the top nine feet of the Maxville limestone at White Cottage.

Silica	3.04
Alumina	1.54
Ferric oxide	0.40
Carbonate of calcium	92.92
Carbonate of magnesium	1.21
Total	99.11[1]

Both of these analyses show a limestone admirably suited to the manufacture of hydraulic cement. Attention has already been called to the conditions of the exposure at these places and especially at Fultonham, where the limestone forms the structural terrace opposite the depot and where the amount of stripping necessary to quarry the stone would be small. Then, too, the field lies within the area of the Coal Measures, and although coal is not mined right at Fultonham it is mined at a number of places only a short distance away, and Fultonham is the shipping point where the trains of coal are made up. Furthermore, it

[1]Op. cit. pp. 100, 101.

has been shown in the stratigraphic part of this paper that the upper half of the stratum is fourteen feet and ten inches in thickness opposite the depot and that this division reaches a maximum thickness of twenty-one and a half feet a mile farther down stream. This additional three to ten feet would make the stone just that much more valuable if its chemical composition remains the same, and it probably does. The great variation in lithology and composition which this stratum has been said to undergo from place to place is somewhat misleading. The fact is the upper part has been unintentionally compared with the lower part (as divided in this paper) or *vice versa,* and since the upper and lower halves are decidedly dissimilar, the supposed variation resulted. Attention must again be called to the pre-Pottsville erosion of the upper surface of the stratum and the resultant variation in thickness of the stratum, and hence the necessity of careful tests. The cross section on the next page (Fig. 6) will help illustrate these various points.

OLIVE FURNACE.

Mr. McQuigg furnished an analysis of the limestone which was taken from the McGugin well. Since it is a very pure stone it probably should also be given, although the number of feet included within the analysis is not known. The analysis follows:

SiO_2	1.10
Al_2O_3	0.23
Fe_2O_3	0.17
$CaCO_3$	98.20
$Mg\ CO_3$	0.13
Phos.	0.039
Total	99.869

The analysis reveals a pure limestone well suited to the manufacture of cement, although, as already stated, the amount of limestone included in the sample analyzed is not known. The thickness of the stratum seems to warrant further investigation, even though the limestone would have to be mined by shafting.

FURNACE FLUX.

The Maxville limestone was formerly quarried at a number of places and used at a still larger number for furnace flux. The stone was worked at Maxville and vicinity in Perry County, at Smith Chapel in Hocking County, at Canter's in Jackson County, and on Niner Ridge in Scioto County. The limestone was used in furnaces at Shawnee and at (New) Straitsville in Perry County, in Winona and Union furnaces in Hocking County, in Washington and Jackson furnaces in Jackson County, in Harrison Furnace in Scioto County, and probably in other furnaces.

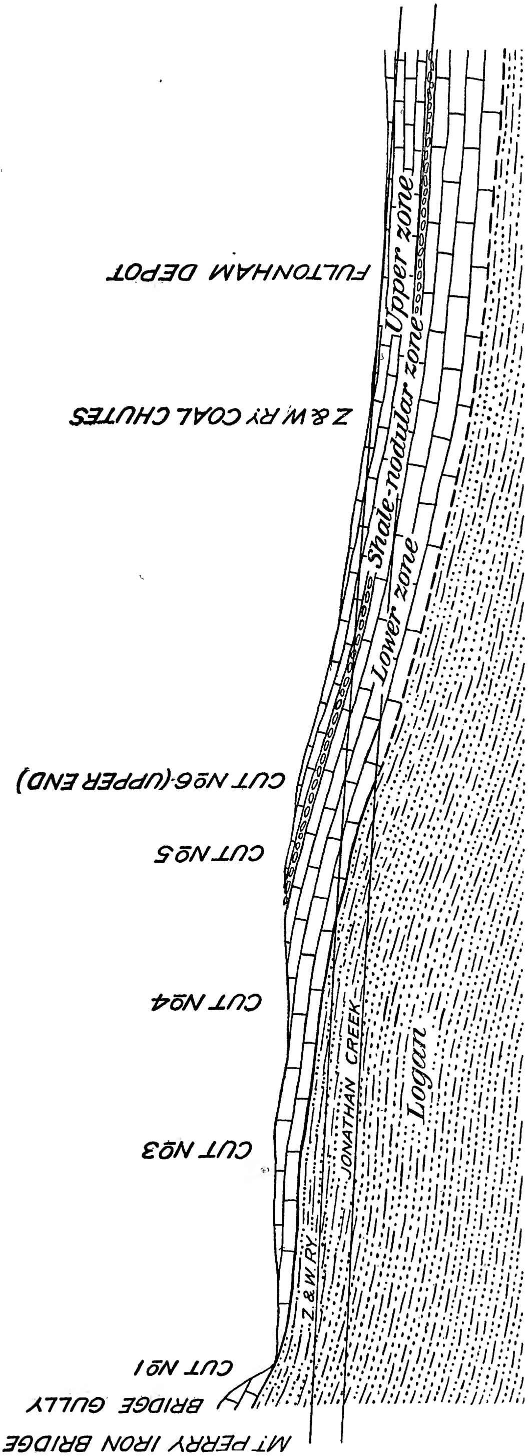

Fig. 6.—A cross section of the Maxville limestone along Jonathan Creek between the Mt. Perry Iron Bridge and a point one mile below the Fultonham Depot. The superjacent rocks have been omitted, but note how the pre-Pottsville erosion plane cuts out the limestone in places and descends deeply into it at others. The sketch shows how one portion of the Maxville is exposed at some points and another portion at others.

These were the old charcoal furnaces, and they obtained their iron ores from the Coal Measure strata of the adjacent hills. But these ores have been practically completely supplanted by the iron ores of the Lake Superior region. The furnaces which they raised and nourished have nearly all passed away with the iron ore industry, and in most cases only piles of rock ruin or heaps of slag remain as monuments to the once widely disseminated industry.

If the Lake Superior District is waning, or in the future should do so, then perhaps the iron ore industry of the Coal Measure hills of Ohio is only slumbering. If slumbering, then perhaps at the awakening the Maxville limestone will again be used as a flux. But this is, at the present, rather too remote a date to warrant further speculation.

There is, however, one kind of furnace flux for which the chemical analyses seem to show the Maxville especially adapted, and that is the flux used by the basic hearth furnaces. These furnaces require a flux as free as possible from silica, SiO_2, and to obtain the desired flux it is often necessary to ship the stone for long distances. One of the Columbus firms, for example, is obtaining limestone at St. Louis, Mo. The analyses already given show the upper twelve feet of the Maxville at Fultonham and the upper nine feet at White Cottage to be low in silica, and the stone from the McGugin well to be very low, and hence at all these places the stone is probably well suited for this use.

LIME.

If the Maxville was rather widely wrought for furnace flux, it was probably even more generally quarried and burned for lime, since the less exacting chemical composition of stone for this purpose wonderfully increased the area of production over that of flux. The Maxville was burned at White Cottage, at Fultonham, rather largely at Maxville, at Canter's in Jackson County, rather extensively at Limeville (Ky.), and probably at many other places. Strata with better natural advantages and better shipping facilities have reduced the competitive price to the critical point, and the Maxville has gone down probably never to rise again in this industry.

FERTILIZER.

The Maxville limestone has been quarried, burned and used as a fertilizer upon the farms where it occurs. It will, probably, be so used again in the future, but such usage can never be other than local.

BUILDING STONE.

The limestone has also been used as a building stone, the court house at Zanesville being constructed of stone from this horizon, quarried at White Cottage. Some of the stone quarried at Fultonham has also been

used for building purposes. At both places the stone is taken from the upper half of the formation, where it is always in definite layers. Since the upper half of the stratum is found to any considerable extent only at these two places, the area of building stone production is very limited. Furthermore, it does not seem probable that it will ever compete with the Berea grit of Ohio or with the Salem (Bedford) oolitic limestone of Indiana.

FOURTH SERIES, BULLETIN 14

IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

GEOLOGY OF THE COLUMBUS QUADRANGLE

By CLINTON R. STAUFFER, GEORGE D. HUBBARD
and J. A. BOWNOCKER

NOVEMBER, 1911

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INTRODUCTION.

Geological surveys have usually had for their prime object the description of natural resources of a geological nature with reference to their utilization by man. This has often made necessary descriptions of fundamental facts, not of direct economic value, such as stratigraphy or rock succession, paleontology or former life, and physiography or surface features, so that the publications have had commonly a wide scope.

Thus far but little has been done by surveys for direct use in colleges and high schools. Illustrations and descriptions in text-books are usually from distant points, with the result that scant information is available to instructors and students of the geology of their own communities.

This bulletin is intended to meet such wants. It is designed for students in colleges who are taking their first course in geology and for teachers in high schools. It is hoped that it will be of service also to those citizens who desire information in concise form of the rocks around them, but who cannot readily follow the usual geological publications. Effort has been made to free this bulletin from technicalities, but in doing this accuracy has not been sacrificed.

The maps which form so valuable a part of the bulletin were prepared by Professors Stauffer and Hubbard, the former the one showing the Areal Geology and the latter the Physiography. The engraving and printing were by the United States Geological Survey.

PART I.

HISTORICAL OR AREAL GEOLOGY.[1]

By CLINTON R. STAUFFER

CHAPTER I.

INTRODUCTION.

Geology is merely a history of the Earth. In other words, it is the study of Nature in its broadest sense. Since we are all a part of Nature and are subject to its laws on every hand, the science of Geology touches our very existence from its beginning to its end. More than that, it reaches far back into the past and grapples with the question of the origin of the Solar System, but more especially of the Earth, long before the germ of life had been brought into existence, and turns to the future with the same determination to wrest from it the secrets of that which lies in store for our planet. It is the broadest of the sciences and is the foundation on which many of our industrial pursuits are built. A lack of knowledge of even the most obvious principles of Geology, and a wanton neglect of those which we really do know, have cost mankind a very considerable amount of money and many lives. We are thus brought to a realization of the importance of the subject before us.

It is hardly to be expected that many people have or will acquire an intimate knowledge of Geology. Yet it seems eminently desirable that everyone should know something about the history of the material, which composes the more enduring part of our State, and have a more particular knowledge of the lakes, rivers, soil and rocks of his immediate surroundings. Certainly no science is easier to acquire and few will give more pleasure than the ability to read from the solid rock the history of the material which so often passes unnoticed under our feet.

Rocks of all kinds which are exposed to the action of the atmosphere, its varying temperature and humidity, gradually disintegrate. The bare rock surface heats rapidly under the action of the sun's rays. This heating causes an expansion of the outer portion or shell. Since rock is a poor conductor of heat, the change in temperature penetrates but slowly and the outer portion, expanding more rapidly than the inner, is fractured or broken loose from the cooler part within. When the rocks are once thoroughly heated and then rather suddenly cooled at the surface a process, which is the reverse of that just outlined, sets in

[1] The portion pertaining to the southern half of the Columbus quadrangle is based on work done by Dr. Prosser and Dr. Cumings; however, in many instances the writer has drawn on his own knowledge of the field.

and again the result is fracturing of the rock. If the cracks in the rocks are filled with water and the change in temperature cools it below 32° F., then the water freezes and the expansion (about one-tenth) resulting therefrom disrupts the rock. Also oxygen, carbon dioxide and water penetrate the crevices and pores of the rock and become a part of its chemical composition. This addition of material means an increase of volume (in granites as high as 80%) and consequently a disruption of the mass, for not all parts are equally affected. Some of these new chemical compounds are soluble in water, especially if it contains organic acids, and hence may be leached out and carried away by ground water. In cases of sandstone, the mineral matter which binds the sand grains together is often soluble and, if dissolved out by ground water, leaves only a bed of sand.

These disintegrating processes are at work not only in the rocks which are actually at the surface, but also in those at some distance below, for the loose outer portion of the surface material is penetrated by the atmosphere while ground water may carry the active chemical agents to a considerable depth and there work changes similar to those which take place at the surface.

So the bed rock, which happens to be near the surface of a land area, is gradually changing into the loose material which we are accustomed to see everywhere. This loose earth, composed of the disintegrated bed rock, is called the mantle rock because it forms a mantle which covers the bed rock more or less completely. Normally the mantle rock, when penetrated from the surface downward, contains larger and larger fragments of rock until finally it grades into the bed rock below. In regions which have been recently glaciated, however, the upper surface of the bed rock is smoothed and striated and the contact between it and the mantle rock is sharp. Such is the case in the Columbus region and will be discussed in Part II.

But if the bed rock is gradually changing to mantle rock why, we may ask, is not the latter much thicker than we find it? To answer this question it is but necessary to recall the natural processes which are working so constantly and quietly about us. Every shower leaves its impression on the surface of the land. A portion, small though it may be, of the loose earth, the mantle rock, is moved down the hillside and into the river below. Once in the river it is swept on with the current until finally it comes to rest as sediment in some great body of quiet water, such as a lake or the sea. If now one shower can move a little of the mantle rock from the hillside, what must be the effect of millions of showers?

But it is with the history of this material after it has come to rest on the bottom of the sea that we have to deal at present. These materials, such as clay, sand, gravel, etc., carried down to the sea by the rivers and deposited there, are called clastic sediments because they are

made up of broken fragments of rock. It is easily seen that not all streams are depositing the same kinds of sediment. Mountain torrents on steep coasts are likely to sweep down very coarse gravel, while on gentle plains the rivers will be sluggish and carry only the finest particles (silt) to the sea. At some localities the change from one kind of sediment to the other is gradual and one may trace the successive steps in the process with a fair degree of accuracy; at other places, however, the change is so abrupt that it forms a striking feature in the sedimentary series. Such differences have led to the division of the rocks into formations. While one kind of material is being deposited, that is, until some decided break occurs in this process of sedimentation, there is naturally a similarity of the material above and below any given point. So long as this continues, we usually call it a single formation. But after the change, whether it comes suddenly or not, a different kind of sediment is found where it did not formerly exist, that is, a new formation has begun. It has thus happened that thousands of feet of varying sediments have accumulated on the sea bottom and the process is still going on.

It is a well known fact that most river water contains lime dissolved from the soil or underlying rock. This is abundantly proved by the coating (boiler-cake) which is often so troublesome in the boilers of engines, and likewise in tea kettles. The continual transfer of this material from the land to the sea must eventually contribute a large amount of lime to the waters of that body. The penetration of the sediments by this lime-laden water, together with the pressure of the overlying material, often cements them into solid rock. Iron and silica sometimes perform the same function. Still other portions of the lime in ocean waters are extracted by marine organisms, such as corals and clams, whose shells or hard parts are made up largely of Calcium carbonate—merely a different form of lime. When these animals die their skeletons are deposited on the ocean bottom and form beds which become cemented into limestone. Some limestones are thought to have originated in other ways, probably by chemical means, but the great body of the limestone deposits is doubtless of organic origin.

Sediments, whatever their origin, frequently contain the remains or traces of organisms, which lived during the time that the deposits were being formed. These remains are usually shells, bones, teeth, tracks, trails or burrows, the impressions of leaves, bark, fruits, etc., but in exceptional cases the entire organism is preserved. All of these remains or traces, which give us some knowledge of the organisms that have existed in past ages, are known as fossils.

On the modern sea shore a certain association of animals (a fauna) is found living on the sandy bottom while a very different fauna may be living on the muds of another part of the shallow waters. Since some forms of sea life are better adapted to the colder waters than

others, faunas vary with the latitude. Moreover it is known that certain species, once abundant, are dying out (becoming extinct) while others are becoming more numerous. The remains of extinct species usually show more primitive characters than are common in living species. This is still more likely to be the case when fossils from the earlier sediments are compared with those of sediments more recently deposited. Hence we may say that fossils vary with the kind of sediment being deposited and with the progress of time. Thus we have the means of classifying the sedimentary formations according to a time scale based on the contained fossils.

It has often been observed that the land and sea are not maintaining definite relations to each other. Thus, some coasts are slowly rising while others are sinking. Bladensburg and Dumfries, in the neighborhood of Washington, D. C., could be reached by sea-going ships in Colonial days, but now are decidedly above tide level.[1] A portion of the coast of Greenland has been sinking for the past four centuries. "Old buildings and islands have been submerged; and the inhabitants have had to put down new poles for their boats, the old ones standing—'as silent witnesses of the change'."[2] Hence great portions of the Earth's surface, which were once beneath the sea, may have been elevated to form a portion of the dry land, while others, which once were a part of the continent, may now be covered by the sea.

If we imagine the present North American land surface to sink, or the sea to rise, so that the waters of the Gulf of Mexico should extend northward and those of the Hudson Bay southward until they would meet at some point in Ohio, then conditions, somewhat similar to those which prevailed in this region while the limestones and shales were being formed, would be restored. Around the higher portions of the land, which would form islands or shoals in this sea, coral reefs would probably be built. Colonies of crinoids might flourish at other points, while the greater portion of the bottom of this shallow or epicontinental sea would probably swarm with clams, snails, crabs, lobsters and every other form of marine life which is now found along the Atlantic coast. When these animals would die their calcareous remains might form deposits of limestone. Such an abundance of life would furnish a most excellent feeding ground for fishes and it is probable that great schools of them would inhabit the region and ultimately contribute their skeletons to the deposit. At another time conditions might be so changed that so much mud would be brought down by running water that the shells of animals would contribute but a small amount to the total deposit, and a fossiliferous shale would result.

It may thus be seen that the bed rock, underneath the thin covering of glacial drift, was once deposited as sediment beneath the sea.

[1] Scott, W. B., Introduction to Geol. 1902, p. 67.
[2] Dana, J. D., Manual of Geol., 4th Ed., 1895, pp. 349-350.

The shales are nothing more than the cemented beds of silt or mud, the sandstone and conglomerates cemented sands and gravels, while the limestone mainly comes of organic origin. When we remember that these sediments have been washed down from ancient hills and carried to the sea or other lodgment basin, just as material is now being transported to the ocean, and that in this process of wear and reconstruction perhaps whole continents have been involved, we must feel a keen interest in these forces and their results.

SEDIMENTARY RECORD.

The mantle of drift, spread over the Columbus quadrangle, is quite irregular in thickness. In the northern part of the city, shale lies

Fig. 7—A small anticline in the Delaware limestone along the east bank of the Olentangy River, below Stratford.

within a few inches of the surface while three miles west of Dublin well-drillers report two hundred feet of glacial drift. Over the greater part of the area, however, bed rock lies so near the surface that it outcrops along even the minor streams.

The outcrops of the various formations, which constitute the rock floor of the section under consideration, are essentially parallel and extend in a northerly and southerly direction. The dip (inclination from the horizontal) of these formations is to the eastward and runs

from twenty to about thirty feet per mile. Such a slight variation from the horizontal is observable only when the elevations of distant outcrops of the same bed are compared. However the strata are frequently so affected by small folds that the dip is temporarily reversed. Some of these little folds may be found along the Olentangy River, south of Stratford, where the Delaware limestone is folded into well developed anticlines and synclines with axes extending nearly east and west (see Figure 7). Other disturbed strata may be seen in the Bedford shale along Rocky Fork northeast of Gahanna (see Plate XVI).

In composition the formations, in stratigraphic succession from west to east, bear an interesting relation to each other. Every gradation from the pure limestone to the quartz conglomerate is to be found within the short space of twenty miles. Just what this means is perhaps a greater problem than may at first appear. Such clastic sediments as mud, sand, gravel, etc., following each other in orderly succession (see Plate XVIII) after the deposition of calcareous material, seems to indicate a shallowing of the basin within which they were formed; but even if this be the chief cause, it is not clear from whence the material came. Moreover it is not strictly true that the shales, or even the sandstones and conglomerates, were necessarily formed in shallower water than that which prevailed during the deposition of the calcareous sediments. Such limestone as results from the accumulation of the hard parts of lime-secreting organisms is not always or even usually a deep sea deposit. Crinoids, corals, brachiopods, mollusks, etc., flourish in our modern seas at slight depths and often near the land. It seems probable, therefore, that factors other than change of depth were also operative. Perhaps one of these was the closing of channels by which the inland sea had maintained its communication with the open ocean. Such a change, resulting from an upward movement of the land (diastrophism), would render the waters temporarily brackish and therefore less favorable for the existence of lime-secreting organisms. More than that, any low lying tracts of land, which may have existed and which were deeply covered with weathered material due to the long period when there was relatively little erosion, would thus be brought into a position favorable for the removal of this weathered mantle by the action of running water and consequently the formation of shale would probably be initiated. While the black shale (Ohio) was being deposited, the sea must have been reduced to the condition of a swamp approaching that of the coal forming period. In fact many of the plant fragments found in this formation are highly carbonaceous, really an impure coal, and the formation itself is characteristically bituminous.

With the advent of the sandy sediments, other changes more profound must have occurred, but what they were is perhaps highly speculative. It is certain, however, that some effective means of shifting sand must have been operative, since the only plausible source of such

material was the disintegration of quartz bearing rocks in the highlands of the old land masses to the north—a long distance from its ultimate resting place.

These various sediments, including the glacial deposits, which come to the surface in the Columbus region, may be grouped together in the following classification:[1]

Cenozoic	Quaternary	(Drift)	Wisconsin Illinoian
	Unconformity		
Paleozoic	Mississippian	Waverlyan	Black Hand form. Cuyahoga form. Sunbury shale Berea grit Bedford shale
	Devonian	Chautauquan and Senecan	Ohio shale
		Erian	Olentangy shale Delaware limestone
		Ulsterian	Columbus limestone
	Unconformity		
	Silurian	Cayugan	Monroe form.

The presence of underlying sedimentary deposits, other than those outcropping, is known from the records of deep wells drilled in this vicinity. The most important of these are the State House well[2] and the well drilled on the bank of the Olentangy River in 1889. These wells penetrated between two and three thousand feet of strata and give us a section, of more or less value, extending down into the Ordovician.

OUTCROPPING FORMATIONS.

A formation is usually considered as outcropping if it is the one immediately underlying the mantle rock.

Monroe Formation.—As indicated in the above table, the lowest of the outcropping formations within this area is the Monroe formation. In the central part of the State, the Monroe is a fine grained compact drab limestone or dolomite which is rather thin bedded and has a distinctly banded structure. Sometimes the freshly fractured surface of the rock has a strong petroleum odor, but that is likely to be the case with any of the limestones of the region. It is not a very fossiliferous formation in any locality and here it is exceptionally poor in animal remains.

[1] Prosser, C. S., Geol. Surv. Ohio, 4th Ser., Bull. No. 7, 1905, p. 3.

[2] Newberry, J. S., Geol. Surv. Ohio, Vol. I, pt. 1, 1873, pp. 113, 114. Also Vol. VI, 1888, pp. 107, 108; 281, 282.

Occasionally, however, *Leperditia alta* and more rarely *Spirifer vanuxemi* have been found. In the northern part of the state, in Michigan and in Canada, the formation contains a considerable fauna. Many of the species found in those localities resemble so closely certain Devonian, rather than Silurian, forms that the exact age of the upper part of the limestone is more or less in doubt. The formation is limited in its surface outcrop to a rather indefinite portion of the west side of the quadrangle. Meager outcrops occur along Mill Creek as well as along Big and Little Darby Creeks, where usually about six or eight feet of rock are to be seen—a mere fraction of the total thickness of the formation.

North of Harrisburg about three miles, and just above the bend of the Big Darby, the contact between the Columbus and underlying Monroe comes to the surface. The outcrops, however, are poor and of little importance other than for the interesting boundary line which they show. Northward from here for the next two miles these limestones may frequently be seen, but never more than a small section is exposed.

The best and most accessible places for seeing the Monroe formation, as well as the Silurian-Devonian contact, are near Georgesville. On the south bank of Little Darby Creek, one mile west of its junction with the Big Darby and on land owned by Mr. E. N. Coberly, there is a very good limestone cliff where the following section was measured by Dr. Cumings:

Columbus limestone.	Thickness.
7. Soft crystalline brown limestone, with pockets of calcite. This rock weathers irregularly, which thus produces a conspicuous honey-combed surface. The residual soil, resulting from its decomposition, has a red color. (The best exposures of this portion of the formation are in a small run in the hillside just a little east of where the creek turns east. These layers are still better shown about 100 feet farther to the east)	7′ 0″
6. Drab or yellowish limestone blotched with darker spots; often flaky and somewhat crystalline. It occurs in a single layer with a surface uneven, but not honey-combed	2′ 0″
Monroe formation.	
5. Thin bedded, uneven, very impure, drab limestone. The upper part contains some seams of calcite, is hackle-toothed, contorted, and weathers with a honey-combed surface	3′ 8″
4. More evenly bedded, very light colored, fine grained compact limestone, in three conspicuous layers, and having a clean vertical fracture	4′ 0″
3. Massive, but weathering into thin irregular layers; bedding planes uneven and wavy. The lower layers are compact and very fine grained	4′ 0″
2. Thin bedded, ash colored, banded limestone, which breaks with a clean vertical fracture	1′ 0″
1. Massive, impure, argillaceous, magnesian limestone, with the color of ashes, and a tinge of yellow. This part of the section is usually covered with talus, but is exposed at intervals to low-water level	5′ 0″

The transition from the Silurian to the Devonian here lacks one of its usual characteristics—the basal conglomerate. This consists of pebbles of the compact banded drab limestone (Monroe) imbedded in a matrix of brown Columbus limestone and forming the basal layer of the latter formation. These pebbles are well rounded and vary in size from a fraction of an inch to three or four inches in diameter. Occasionally there is some quartz sand intermingled with the pebbles and at places this is so abundant that it has been called a sandstone. The thickness of this conglomerate is usually about six inches and it rarely exceeds two feet. It is almost universally present where this contact comes to the surface in the central part of the state. One of the best places for observing the conglomeratic phase of this horizon is along the Big Darby Creek, about two miles above Georgesville. Here on the west bank the Messrs. Eckles have opened a small quarry to supply a neighborhood lime-kiln, and have thus laid bare a small section of rock with an excellent exposure of the conglomerate. The occurrence of such a conglomerate shows that the sediments of the Monroe formation had already been consolidated into a limestone and had been subjected to erosion before the deposition of the Columbus limestone took place. The meaning of this is probably that the sea in which the Monroe formation was deposited had withdrawn and the area in question was thus converted into dry land. Later the sea returned, from an easterly direction, and the pebbles, mixed with the basal sediments of the lower part of the Columbus limestone, were formed by wave action on the rocky formations of the coast. How much sediment was removed by erosion, or how many of the intervening formations of other localities were never deposited here, is uncertain; but a very considerable portion of the upper part of the Silurian and somewhat more than the entire lower Devonian, is now wanting. Hence the Columbus limestone is said to rest unconformably on the Monroe formation.

Columbus Limestone.[1]—Succeeding the Monroe formation, as above stated, are about 105 feet of calcareous and magnesian deposits which have received the name, Columbus limestone (see Plate XII). Of this formation, the lower 40 feet consist of a brown magnesian limestone containing much bituminous matter. It has a slightly banded structure, which is not nearly so pronounced as that of the formation just considered, and is more or less wavy. The beds or layers are massive, irregular, and rather indistinctly separated. Small masses of chert occur at more or less irregular intervals and occasionally pockets of calcite crystals are found. Although these layers usually show little sign of crystallization, sometimes blocks may be found which glisten with cleavage faces of calcite. Fossils are rare in this portion of the formation and those that have been found usually occur as moulds and

[1] For a more detailed account of the Middle Devonian formations, see Stauffer, C. R., Geol. Surv. Ohio, 4th Ser. Bull. No. 10, 1909.

casts which are poorly preserved. The barrenness of organic remains is probably not due to a poverty of its fauna during the time of the deposition of the original sediment, but to subsequent changes that have affected these layers. Chemically they approach a true dolomite[1] and like all other metamorphic processes, dolomitization frequently proves fatal to the preservation of fossils.

The upper 65 feet of the formation consist of highly calcareous crystalline gray limestone, which is very fossiliferous. Although the layers are usually even bedded, the bedding planes are sometimes uneven. This is due at times to stylolitic (hackle-tooth) structure and again to ripple-marks. It is the portion of the formation so extensively quarried at Marble Cliff and the familiar crushed rock used as a base in paving the city streets.

The Columbus limestone is doubtless the approximate equivalent of the Onondaga of New York, the Dundee of Michigan, the Corniferous of Ontario, and the Jeffersonville, including the Geneva, of Indiana and Kentucky. This is clearly demonstrated by the abundant fauna, many species of which are common to the various localities mentioned.

There are several features of special interest, exhibited by the upper portion of this formation, which deserve mention here. About nine feet below the top of the formation the "smooth rock" occurs.[2] This smooth plane or layer, as it is sometimes called, resembles a perfectly developed slickensides analogous to that frequently seen along a fault plane. Fossils occurring in it are planed off as smoothly as on a glaciated surface. Possibly it is a plane along which motion, between two portions of rock, has taken place—a shear plane—but the presence of wave-marks on some portions of the smooth surface renders this explanation doubtful. It has its most perfect development at Marble Cliff and State Quarries, but may be traced northward at least as far as Dublin. Sometimes, as at Casparis quarry, the shearing, if such it be, occurred along two parallel planes separated by an interval of about a foot; usually, however only one is to be seen.

The upper six or eight inches of the formation are frequently filled with the plates and teeth of fishes, and thus constitute the "bone-bed".[3] "Here we have the assemblage of millions on millions of generally imperfect but mostly recognizable organs or fragments of the bony structure of the forms of fish life most characteristic of the Devonian age".[4] These bones and teeth are in an excellant state of preservation, retaining even their original luster. The "bone-bed" is co-extensive with the outcrops of the central part of the state and is even well enough defined at Sandusky to be recognizable. An excellent place to see this layer is in the small run that enters the Scioto River from the east at

[1] Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, pp. 615, 616.
[2] Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, p. 610.
[3] Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, pp. 610, 611.
[4] Newberry, J. S., Mono. U. S. Geol. Surv., Vol. 16, 1889, p. 30

The Columbus limestone near Marble Cliff.

Fishinger's bridge. The occurrence of such a persistent "bone-bed" in the upper few inches of the formation leads to the suggestion that perhaps this portion of the Devonian sea, teeming with its myriads of small organisms, was an exceptional feeding ground for those fishes whose remains contributed to its formation. Another possible reason for so remarkable an increase in the number of fish remains,[1] and especially at the top, may have been the wholesale destruction of these animals by some sudden change in the condition of the sea or by some agency of unknown cause. Notable modern instances of this are the destruction of the tile fishes along the Atlantic coast of North America in 1882 when it was estimated that a layer of fish several feet thick was formed over the entire sea-bottom of the region affected; or again along the Indian coast in 1897, when the Sumesar River was dammed by fish killed during the earthquake.[2]

Another feature to be mentioned is the chert beds. The occurrence of chert in limestones is a common phenomenon of many horizons and of almost every locality where they outcrop. In central Ohio it is more plentiful in the Delaware than in the Columbus limestone; however, in the latter there are several well defined zones. The more important of these is the zone located about 55 or 60 feet below the "bone-bed." This zone thins out to the north, but at the Storage Dam it measures about 9 feet. The chert is mainly in concretionary masses, the silica of which "was probably deposited in the form of the siliceous shells and spicules of plants and animals, and was disseminated through the sediments as originally formed." Subsequently it has been "aggregated into nodules of chert"[3] and, by the process of replacement, changed calcareous to siliceous fossils.

Excellent outcrops of the Columbus limestone may be found along the Scioto River from Columbus northward beyond the limits of the area under discussion. The quarries at Marble Cliff (see Plate XII) give a section which may be considered as typical of the upper part and a small portion of the lower may be seen just below the Columbus Storage Dam, while the entire thickness of this massive brown portion may be seen along the river near Bellepoint.

The following is a section measured near the north end of the Casparis quarry east of the Scioto River:

Delaware limestone.	Thickness.
12. Rather thin bedded bluish brown limestone containing some chert in the upper part, and all much weathered	5′ 0″
11. Thin bedded bluish limestone, containing great quantities of black chert in definite layers	5′ 10″

[1] Geikie, Archibald, Textbook of Geol., 4th Ed., 1903, p. 375.

[2] Oldham, R. D., Mem. Geol. Surv. of India. Report on the Indian Earthquake of June 12, 1897, p. 80.

[3] Chamberlin, T. C., and Salisbury, R. D., Textbook of Geol., Vol. 1, 1905, p. 438.

		Thickness.	
Delaware limestone—Concluded.			
10.	Massive bluish limestone, with much black chert intermixed. The upper part is contorted, or more or less concretionary in appearance	3′	8″
9.	Shale and some rather thick layers of bluish brown limestone, also containing a considerable quantity of black chert	5′	0″
8.	Soft thin bedded grayish brown shale, with some chert	0′	6″
Columbus limestone.			
7.	Well defined "bone-bed"	—	—
6.	Massive bluish gray sub-crystalline limestone, containing some gray white chert. *Spirifer acuminatus* and *Platyceras dumosum* are characteristic fossils	9′	4″
5.	Smooth layer	—	—
4.	Very fossiliferous and fairly massive gray limestone. The weathered surfaces of this rock show numerous corals	8′	0″
3.	Massive fossiliferous gray limestone. These layers show some prominent joints running approximately north and south. Characterized by the presence of such large cephalopods as *Gyroceras cyclops*	13′	0″
2.	A layer of massive gray limestone exceedingly full of *Spirifer gregarius*	3′	6″
1.	Massive fossiliferous gray limestone, extending to the bottom of the quarry	2′	6″

The quarries farther south are perhaps better for purposes of collecting fossils. The banks of the river, and especially the west bank, from Casparis south to the old State Quarries are simply shattered either by active quarries or abandoned pits. Among these the collector may find a wealth of fossils which is scarcely exceeded at any other locality.

Delaware Limestone.—The abrupt change from the pure organic sediments of the Columbus limestone to the argillaceous cherty blue limestones and calcareous brown shales of the Delaware is most strikingly illustrated in the sections of central Ohio. The five or six feet immediately succeeding the "bone-bed" consist of brown shale (see Plate XIII) in which Whitfield discovered a fauna which led him to correlate it with the horizon of the Marcellus shale of New York.[1] These fossils are mainly of species belonging to such genera as frequent the seas when black shale conditions prevail and may be found in nearly every outcrop of this horizon. The fauna of the Delaware limestone as a whole is intimately related to that of the Traverse group of Michigan and the Hamilton beds of New York, although it still retains, here in central Ohio, certain forms which are also of Onondaga age. These latter, however, are such as are usually common to the two formations mentioned, and hence it may be safely said that none of the characteristically Onondaga (Columbus) limestone fossils are known to have withstood the changed conditions of the Marcellus shale horizon. There is about thirty-six feet of the Delaware limestone in central Ohio, but it thickens notably to the north and also becomes a purer limestone. At Delaware, from which city the formation takes its name, it has been used quite extensively as a building stone.

[1] Whitfield, R. P., Proc. Am. Ass'n Adv. Sci., Vol. 28, 1880, p. 298; also Geol. Surv. Ohio, Vol. 7, 1893, pp. 432, 433.

PLATE XIII.

The shaly base of the Delaware overhanging the massive Columbus limestone.

Nearly every outcrop of rock along the Scioto River shows at least a small fraction of this formation. An excellent exposure may be seen along the Dublin pike on the east side of the river just beyond Fishinger's bridge, and the entire formation outcrops along Slate Run,[1] which passes through the grounds of the Columbus Fishing Club not far beyond. Another outcrop which is equally as interesting and shows the Olentangy shale somewhat better is to be found along Bartholomew Run.[2] This run is located a mile north of the Franklin-Delaware county line and enters the Olentangy River from the west, heading near Powell. The following section gives, in some detail, the rocks outcropping along this run.

		Thickness.	
Ohio shale.			
25.	Black shale, rather thin bedded and considerably weathered. It contains a number of large spherical concretions	16′	0″
Olentangy shale.			
24.	Soft bluish marly shale, the upper part yellowish in color	3′	10″
23.	Layer of flat, more or less disc-like, calcareous concretions	0′	7″
22.	Soft blue marly shale, with some brown layers	7′	2″
21.	Layer of impure bluish limestone	0′	6″
20.	Bluish marly shale, with some thin bands of brown or black shale	2′	0″
19.	Black shale, containing some fragments of fossil plants	0′	7″
18.	Marly blue shale	1′	0″
17.	Black shale cut into small blocks by two conspicuous systems of joints. Iron pyrites common	0′	3″
16.	Marly blue shale	1′	8″
15.	Two distinct layers of impure blue limestone	0′	4″
14.	Bluish green marly shale, containing thin bands of brown shale	2′	4″
13.	Brown shale with marl-filled marks, or trails of marine "worms." It also contains fragments of plants	0′	3″
12.	Soft bluish green marly shale, containing great numbers of small limestone concretions	5′	0″
11.	Brown shale with some "worm" trails through it, and containing a few bryozoans(?)	0′	3″
10.	Bluish green shale, soft and gritless, showing some trails of marine animals	2′	4″
Delaware limestone.			
9.	Cherty blue to brown shaly limestone, the top of which is penetrated by the "worm" holes and filled with blue marl from above. Fish teeth and bones, somewhat water worn, and a few pebbles are also included in this shaly mass. At the present time this is the only known exposure of this contact	0	5″
8.	Very cherty bluish brown limestone. Layers rather even and sparingly fossiliferous. This is the zone which Winchell called "Tully limestone," and which Newberry conceded to contain a Hamilton fauna	9′	4″
7	Granular layer of grayish brown limestone containing much iron pyrites which, in some cases, has replaced the original substance of the fossils. This thin zone contains a varied fauna notable among the species of which is the small globular coral, *Hadrophyllum d'orbignyi*	0′	8″
6.	Massive bluish limestone containing very little chert	2′	0″
5.	Thin bedded shaly limestone with much black chert	1′	0″

[1] Prosser, C. S., Jour. Geol., Vol. 13, 1905, pp. 426–430.
[2] Winchell, N. H., Geol. Surv. Ohio, Vol. 2, pt. 1, 1874, pp. 288, 289.

Delaware limestone—Concluded.	Thickness	
4. Blue to brown limestone containing iron pyrites and black chert intermingled and much contorted. These layers, together with the two just above, usually contain many specimens of *Grammysia bisulcata*	4′	0″
3. Rather massive blue limestone with some chert and shaly layers. *Tentaculites scalariformis* is a common fossil	8′	0″
2. Thin bedded brown calcareous shale with layers of black chert. It contains the Marcellus shale fauna	7′	0″
1. Brown limestone, somewhat shaly and probably a part of the above zone. These layers extend to the level of the run below the highway bridge	2′	6″

In the runs to the north of this there are many good sections of the Delaware limestone. Among these may be mentioned that in Deep Run[1]

Fig. 8—The Olentangy shale, showing its basal portion and the uneven contact with the Delaware limestone below, as shown along Bartholomew Run in Delaware County. The observer stands on the summit of the Delaware limestone.

and the one on the Amelia Case farm, south of Liberty road. The Delaware limestone is not as fossiliferous as the Columbus limestone, but frequently layers may be found which have fossils in abundance. The fauna contains a much smaller number of species and is made up in part, as previously indicated, of species left over from Columbus time and in part of true Hamilton forms.

Olentangy Shale.—With the above formation may be classed the soft argillaceous blue deposit known as the Olentangy shale (see Plate

[1] Prosser, C. S., Jour. Geol., Vol. 13, 1905, pp. 430–433.

"High Banks" along the Olentangy River north of Worthington. The illustration shows the clay-like constituency of the Olentangy shale and the firmer overhanging Ohio shale.

XIV). They are successive stages in the general change from pure limestone to the strictly clastic deposits that follow. The Olentangy shale contains several thin layers of argillaceous limestone which are quite persistent in position. Towards the upper part of the formation occur layers of the black shale, similar to the Ohio, alternating with the soft blue layers, and also several more or less definite layers of flat calcareous concretions. Notwithstanding this, however, the contact with the Delaware limestone is sharp and the transition to the overlying Ohio shale is often sudden (see Figure 8). Sometimes the black shales are deposited on a surface which is decidedly uneven, with places where some sandy material has been found at the contact. Such contacts may be found at "Dripping Rock" on the Amelia Case farm and at the type section along the Olentangy River at Delaware.

The Olentangy shale is very poor in fossils. The only traces of animal remains found within this area are a few fish teeth, a crinoid stem, one pelecypod shell, which is probably a *Nucula*, and a bryozoan. Aside from these, however, there are several layers of a brown to purplish blue shale, occurring quite persistently in the lower part, which show markings thought to be "worm" trails. It is generally believed that this shale is of Hamilton age and this is probably true. Certainly its lithological appearance suggests such a disposition of the formation and so does its meager fauna in the outcrops just north of this region. That Newberry's Prout limestone[1] and marl is the northern equivalent of the Olentangy shale, is reasonably certain. The preceding section, measured along Bartholomew Run, gives a very good idea of the general make-up of the Olentangy shale (see Figure 8).

Ohio Shale.—The Ohio shale (see Plate XV) is the last formation of Devonian age in central Ohio. In fact it is probable that even the upper part of it may prove to be of Waverlyan age.[2] "The shale is brownish or bluish black in fresh exposures, but weathered surfaces have a distinctly blue color."[3] This statement by Orton, while generally true, does not always hold for weathered surfaces. Frequently they retain their characteristic black color, except for the iron stains which may color the fragments a dull brown. While this shale is quite firm and somewhat massive at first, it soon falls into more or less thin laminae which finally break up into small fissile fragments and in the end weather into a rather stiff clay. It contains a considerable amount of iron pyrites, hence the dull brown of the weathered surface above referred to. The shale exhibits two quite regular systems of joints which, along Rocky Fork, are approximately northeast and northwest in direction.

A feature characteristic of this formation is the occurrence of large

[1] Newberry, J. S., Geol. Surv. Ohio, Vol. 2, pt. 1, 1874, pp. 189, 190
[2] See Ulrich, E. O., Bull. Geol. Soc. Am., vol. 22, 1911, correlation table II, opp. p. 608.
[3] Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, p. 634.

"iron-stone" concretions at several horizons (see Figure 9). They sometimes measure six feet or even more in diameter and are nearly perfect spheres, although there is some variety in form. Frequently the bedding planes may be traced into the concretion, showing that at least a part of the original shale matter is included within the mass. These concretions, in common with most others, are thought to be secondary products formed *in situ* by the aggregation[1] of like matter, usually about

Fig. 9—Concretions weathered out of the Ohio shale. Bartholomew Run.

some fragment of foreign material as a nucleus. This may be suspected from the fact that the shale layers are heaved up over and depressed below the concretions, and from the uniformity of composition of the individuals especially in concentric layers. The nuclei of these concretions are frequently found to be crystalline masses; such minerals as calcite, barite and selenite having been found. In other cases organic matter, such as a fish bone or a piece of wood,[2] has served as a center about which the accumulation occurred. These concretions are usually more frequent in the lower forty or fifty feet of the formation.

In the upper part of the formation calcereous bands from a fraction to several inches in thickness frequently occur. These exhibit the peculiar "cone-in-cone" structure common in several of the Ohio formations.[3] The cones are in two series, one with the bases upward and the other with the bases downward. The origin of this structure is un-

[1] See Chamberlin and Salisbury's Textbook of Geol., Vol. 1, 1905, pp. 438, 490-493.
[2] Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, p. 635.
[3] Newberry, J. S., Geol. Surv. Ohio, Vol. 1, pt. 1, 1873, p. 211.

PLATE XV.

The Ohio shale, with concretions in place, at "The Narrows," about $1\frac{1}{4}$ miles north of Worthington.

known. It has been referred to concretionary action, but probably it is in some way connected with the compressive stresses developed by the load of overlying sediments. Near the upper limit of the formation is a layer of numerous small flat concretions of iron pyrites. This layer is rather persistent in the vicinity of Central College and to the south.

Aside from the impressions of long flat leaves of certain plants, spore cases, a few *Calamites*, the fossil wood associated with some concretions, and occasional fish bones, the great body of this formation is practically barren of fossils in this region. In the extreme upper portion, however, fossils like those of the Cleveland shale are sometimes found. Some of these are very similar to the forms occurring in the Bedford shale.

The Ohio shale becomes the St. Clair shale[1] of Michigan and the New Albany black shale of Indiana[2] and Kentucky. These deposits are supposed to be of Genesee age. In all probability they represent the sediment accumulated in this section of the sea while the Genesee, Portage and Chemung, in part, were being deposited in New York.[3]

There are numerous excellent sections of the Devonian shales to be found in the deep valleys of the tributaries to the Olentangy River, from Stratford to Worthington and even at North Columbus. Notable among these are the outcrops at High Banks, Glen Mary, the Narrows, etc. The shales of all these sections are, however, practically identical.

The following section, which was measured in the Narrows, shows the variable composition of this black shale as it occurs in central Ohio:

Ohio shale.		Thickness.	
17.	Drift	4′	0″
16.	Black shales	38′	8″
15.	Bluish gray shales alternating with black, and all apparently more fissile than that below	6′	0″
14.	Layer of cone-in-cone	0′	1″
13.	Bluish gray shales alternating with black shale	15′	4″
12.	Bluish gray shales with several layers of cone-in-cone	0′	6″
11.	Black shales with some bluish gray layers	6′	8″
10.	Black shales with few or no concretions	16′	0″
9.	Black shale containing a great many spherical concretions	21′	4″
8.	Black shales showing streaks of bluish gray running through the beds. Also some bluish gray shales alternating with the black, and this is especially true in the upper part	10′	8″
7.	Black shales alternating with bluish gray shales	6′	4″
6.	Black shales showing prominent oblique joints. Direction of jointing, northeast and southwest	9′	8″
5.	Band of bluish gray shales	0′	8″
4.	Black shale	0′	6″
3.	Band of bluish gray shales	0′	10″
2.	Black shale with very prominent joints running northeast and southwest. This shale contains numerous small iron pyrites concretions and some of the usual large spherical concretions	8′	8″
1.	Covered interval to the level of the Olentangy River	6′	8″

[1] Geol. Surv. Mich., Vol. 3, 1876, pp. 64-68; also idem, Vol. 5, pt. II, 1895, p. 21, 22; and idem, Vol. 7, pt. I, 1900, pp. 25-30.

[2] 5th Ann. Rept. Geol. Surv. Ind., (1873), 1874, p. 158; also idem, 25th Ann. Rept., (1900), 1901, pp. 340, 341, 532, 533.

[3] Newberry, J. S., Geol. Surv. Ohio, Vol. 1, pt. 1, 1873, pp. 69-71.

Along Alum Creek, which crosses the northeast quarter of the quadrangle from north to south and joins the Big Walnut a short distance southeast of Columbus, excellent outcrops of the Ohio shale occur; in fact the valley of this stream lies wholly within this formation. About the best of these outcrops is that along the run at Cheshire, at the extreme north end of the quadrangle, where some forty feet of the black shale may be seen. Another very good section may be found just east of Blendon, along a run entering Alum Creek from the east.

The key to the stratigraphy of the east half of the quadrangle is to be found along Big Walnut Creek, although in the southeast quarter interest is somewhat divided among Big Walnut, Black Lick and Little Walnut Creeks. The former of these streams flows almost along the line of outcrop of the lower Waverlyan formations; in fact, south of Galena, the Bedford shale was found west of this stream only at Central College. Many places where the east bluff has a fine outcrop of shale, the west, at no great distance, will show nearly all till (glacial clay and boulders). This is partly due to the presence of a buried pre-glacial valley, along the eastern wall of which the modern Big Walnut Creek flows from Galena southward.

Bedford Shale.—With the Bedford shale begins the Mississippian system and the Waverlyan series of classic geological literature. The Waverlyan is recognized in Michigan,[1] where it has been called the Marshall series.[2] It is also known to be closely related to the Knobstone of Indiana,[3] and the Kinderhook of farther west. The Bedford shale is usually an argillaceous deposit (see Plate XVI) varying in color from bluish gray to red or chocolate brown, the red color usually being confined to the middle portion. Where the outcrop is fresh, as in the bed of a stream, the layers appear massive, but on exposure they soon weather into a sticky red or yellow clay. A fine example of this formation in weathered condition may be seen in the hills east of Central College. Here the Bedford shale forms a line of bluffs along the east bank of Big Walnut Creek where the soft and easily eroded shale has assumed a most striking topography resembling, to a limited extent, that of the "Bad Lands" of the West. The color of the central portion of the formation is so conspicuous here as to have fastened the name "Red Hills" upon this locality.

In the lower part of this formation, especially in the northeast quarter of the area, are several layers of small flat argillaceous concretions which show a decidedly concentric structure. Layer after layer may be broken off by the blow of a hammer. An occasional fossil has been found in these concretions. In the southeast quarter of the quadrangle, near Lithopolis, very much larger concretions of an irregular

[1] Geol. Surv. Mich., Vol. 3, 1876, pp. 69-101.
[2] Idem, Rept. Prog., 1861, pp. 80-88.
[3] 25th Ann. Rept. Geol. Surv. Ind., 1900, pp. 339, 340.

PLATE XVI.

The lower part oi the illustration shows the contorted condition of the Bedford shale; and the upper, the basal layers of the Berea grit along Rocky Fork, east of Gahanna.

shape are often found. One of the most notable characteristics of the formation in this part of the state, and the same is true in the vicinity of Cleveland, is the disturbed condition of the sediments forming the upper portion. These layers are frequently much contorted and sometimes even crushed while the overlying Berea is little or not at all affected. The nature of the material of which the Bedford shale is formed indicates that it was probably deposited some distance from shore. Perhaps at the outer margin of these mud deposits, or even elsewhere, steep sub-marine slopes occurred. The slumping or superficial faulting[1] of such deposits would result in the contortion of the layers, especially if the material was sufficiently tenacious to hold together.

Dr. Prosser considers the prominent concretionary layer occurring along Rocky Fork as forming the base of the Berea grit[2]. This is possibly the proper boundary line for that locality, but it must not be expected that such a layer usually or even often marks the contact. Indeed it is frequently impossible to say where the shale ends and the sandstone begins. The upper part of the Bedford is usually arenaceous. Gradually thin layers of sandstone begin to appear and these keep increasing in number until the shale is in the minority and finally disappears. Moreover these thin sandstone layers are well ripple-marked, showing the same shore conditions that existed during the deposition of at least a large part of the Berea. Such is the condition of these sediments along Big Walnut Creek between Galena and Sunbury. However along Rattlesnake Creek, near its junction with Big Walnut Creek, there is a massive concretionary layer which, from the fact that it marks the real beginning of the sandstone, may possibly be taken as Berea grit and hence probably the beginning of that formation. However the usual sediments of the Berea are rather coarser and more massively bedded than those of the sandy layers in the Bedford. Hence there is a disposition on the part of some geologists to throw all these questionable central Ohio beds into the Bedford, leaving only the massive coarse sandstones at the top in the Berea.

The Bedford shale is also one of the essentially non-fossiliferous formations. From one to two feet of the basal layers, however, are frequently very full of fossils. This fauna is no less remarkable in its association of species than is its occurrence here among these almost barren deposits. While it contains a Devonian element linking it, in a general way, to the Hamilton,[3] yet its affinities are more nearly with the Kinderhook, which itself contains a Hamilton element. The Rockford limestone of Indiana and the Glen Park limestone[4] of Illinois carry related faunas, a fact which points to a possible solution of the problem.

[1] Chamberlin, T. C., and Salisbury, R. D., Textbook of Geol., Vol. 1, 1905, p. 527.

[2] Prosser, C. S., Jour. Geol., Vol. 10, 1902, pp. 276, 278; also Am. Geol. Vol. 34, 1904, p. 340, foot note.

[3] Herrick, C. L., Rept. Geol. Surv. Ohio, Vol. 7, 1894, p. 507.

[4] Weller, Stuart, Trans. Acad. Scil., St. Louis, Vol. 16, No. 7, pp. 467, 470.

Over Ohio and eastward the Hamilton fauna disappeared during the deposition of the Black shales, while in the west it continued to flourish and undergo changes due in part to the usual processes of evolution and again to the addition of some new species. A decided deepening of this Ohio portion of the sea probably occurred at the beginning of the Mississippian and with it the faunas of the purer western sea migrated across Indiana and Kentucky into Ohio. Hence the Bedford fauna is decidedly western in its affinities with here and there an eastern species, while the entire fauna still bears a marked resemblance to its ancestral association of species.

The outcrops which furnish good sections of the Bedford shale are so numerous that there is little necessity in calling attention to them. The sections here given are selected because they are fairly accessible and also show some of the succeeding formations excellently.

The following is a combined section of the outcrops occurring along Rocky Fork from its union with Big Walnut Creek below Gahanna to the upper part of the tributary which flows through New Albany.

		Thickness.	
Cuyahoga formation.			
18.	Thin bedded sandstones and some bluish colored shales. This portion of the section is exposed along the tributary flowing through New Albany	50′	0″
17.	Soft bluish shale	5′	0″
Sunbury shale.			
16.	Covered interval, most of it probably belonging to the Sunbury shale	10′	0″
15.	Fissile black shale, iron stained, and somewhat decomposed. The lower two or three inches contain quite an abundance of two or three species of Brachiopods. This portion is best exposed along a small tributary at the bend of Rocky Fork just south of the highway, where the Ealy mill formerly stood	25′	8″
Berea grit.			
14.	Rather massive sandstone layers, many in lenticular beds, and some showing ripple-marks. A layer of marcasite occurs on top	17′	6″
13.	Layers of fine grained sandstones from a fraction to ten inches in thickness, and well ripple-marked. Some layers are much contorted, in places, and contain local beds of shale	8′	6″
12.	Arenaceous gray shale, which grades into the sandstone up stream. It contains some thin layers of ripple-marked sandstones	12′	0″
11.	Concretionary layer, which is thought to form the limiting layer of the Berea	1′	0″
Bedford shale.			
10.	Soft argillaceous blue shales, becoming arenaceous towards the top. Some of the slab-like fragments when freshly exposed show marks resembling the impressions of plant stems	38′	8″
9.	Soft argillaceous gray mottled shales	8′	0″
8.	Soft fissile red to chocolate brown shale. These layers weather rapidly into a stiff clay	25′	6″
7.	Soft argillaceous blue shale, quite fissile and much jointed.	15′	6″
6.	Argillaceous blue shale, very fossiliferous and especially so near the base	2′	0″
5.	Dark bluish brown rather soft shale, containing some fossil shells and worm trails (?), the latter cast in iron pyrites.	0′	4″

Ohio shale.	Thickness.	
4. Black shale prominently jointed (joints N. E. and N. W.), and much iron stained	5′	0″
3. Covered interval (aneroid reading)	5′	0″
2. Black shale	10′	8″
1. Black shale with several layers of "cone-in-cone" to level of Big Walnut Creek	8′	10″

The Bedford shale is well exposed at Taylor's station on the Pennsylvania and the Baltimore and Ohio Railroads, where it is being used in the manufacture of brick and tile. The contact with the Ohio shale may also be found at that place.

Along Duncan Run, which enters Big Walnut Creek a mile and a quarter north of the Franklin-Delaware county line, there is an exceptionally fine section through the greater portion of the Waverlyan series and into the Devonian. The following section gives the gross measurements taken in the cut made by this run.

Cuyahoga formation.	Thickness.	
11. Blue to gray sandstones in layers from a few inches to six or eight in thickness	5′	0″
10. Bluish gray shale, alternating with shaly sandstones, the surface of which show some marks resembling impressions of plant stems or trails of animals	10′	0″
9. Gray shale, not well exposed	5′	0″
Sunbury shale.		
8. A fissile black shale. The contact with the Berea grit is shown back of Harlem, but the contact with the Cuyahoga formation is slightly covered	30′	0″
Berea grit.		
7. Buff to bluish gray fine grained sandstones, the upper layer much iron stained. The lower layers are rather thin shaly and well ripple-marked. At Harlem this stone has been quarried and crushed for road material; for which purpose, when mixed or covered with crushed limestone, it is said to serve excellently. In the quarry here it is a fine-grained bluish sandstone, rather compact and often banded	40′	0″
Bedford shale.		
6. Mottled and gray argillaceous shales, with some sandy layers	28′	6″
5. Soft red or chocolate brown shales	16′	0″
4. Gray shales with a few thin layers of chocolate brown shale.	12′	4″
3. Layer of very compact hard red or chocolate brown shale.	0′	4″
2. Soft gray argillaceous shale containing fossils in the lower part	2′	10″
Ohio shale.		
1. Firm black shale to level of Big Walnut Creek	55′	0″

From this section it will be observed that the Bedford shale decreases in thickness to the northward. By the time the Sunbury region is reached an even greater decrease is noticed, while the simultaneous thickening of the Berea grit is a feature of the northward sections. This variation is somewhat relieved, however, if the lower thin bedded sandstones are considered as a part of the Bedford shale.

Berea Grit[1].—The Berea grit is the earliest persistent sandstone formation occurring in central Ohio. It is a rather fine grained gray to buff colored rock laid down in beds of varying thickness which usually become more massive towards the top of the formation. The beds frequently show a tendency to feather out or to increase in thickness as traced along a cliff. Distortion or concretionary effects (see Figure 10) are common throughout a large part of the formation as defined in central Ohio. This condition may frequently be seen to pass into the ordinary layers of the formation. The thin layers, and many of the thicker as well, are excellently ripple-marked. These ripple-marked

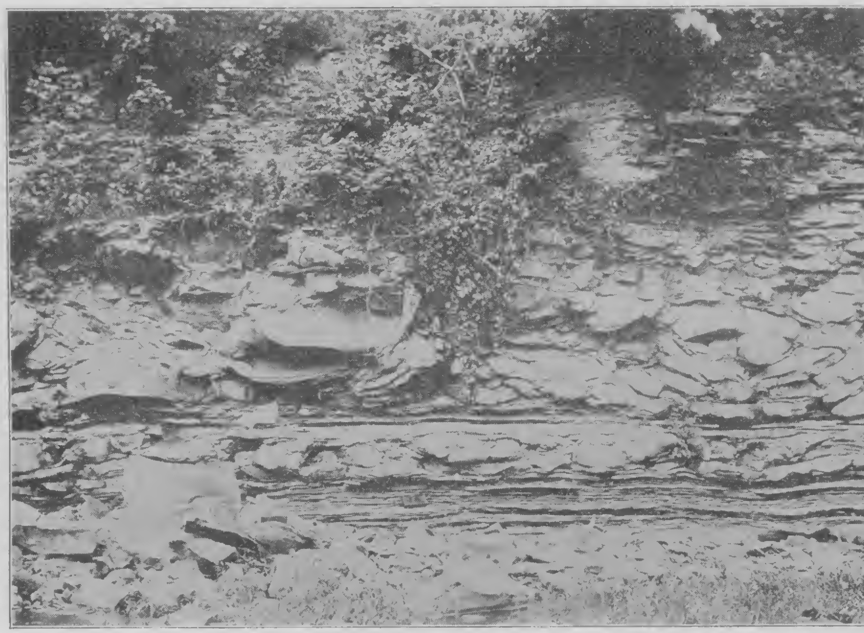


Fig. 10—The peculiar concretionary structure common in the Berea grit, at Sunbury.

layers are sometimes contorted into various shapes, showing that whatever produced the twisting of these beds was operative since the deposition of the sediment and not contemporaneous with it. A notable feature of this formation, and one worthy of mention since it is so persistent, is the occurrence of a layer of marcasite on the extreme upper surface. The decomposition of this sulphide of iron gives rise to the hydrogen sulphide of the sulphur springs to be found along Rocky Fork.

Fossils are rare in this formation, in fact none were found in the outcrops of this entire region. As already mentioned, the Berea grit is quite variable in thickness. In the southeastern part of the area it lies unconformably on the Bedford shale and is reduced to about four feet, while at Sunbury it is probably more than sixty-five feet in thick-

[1] Berea sandstone is often used instead of Berea grit.

ness. The Berea grit takes its name from the village of Berea, Cuyahoga County, where the formation is extensively used in the manufacture of grindstones, for building stone, curbing, flagstone, etc. In southeastern Ohio this formation becomes one of the important oil and gas horizons.

The Berea grit is well shown in the sections just given. The following section, which was measured along Rattlesnake Creek opposite the village of Sunbury, shows a greater thickness of this rock:

		Thickness	
Cuyahoga formation.			
12.	Soft blue shale, composing the base of the formation	5′	0″
Sunbury shale.			
11.	Meager outcrops of bituminous black shale, somewhat iron stained	12′	0″
10.	Partly covered interval of black shale	5′	0″
Berea grit.			
9.	Rather thin bedded gray to buff sandstone. The upper four-inch layer contains a great deal of sulphide of iron (Aneroid reading)	25′	0″
8.	Fairly thick layers of sandstone showing a lenticular shape and interbedded with thin layers	15′	0″
7.	Concretionary masses of sandstone with thin shaly layers, all more or less disturbed	5′	0″
6.	Ripple-marked thin shaly sandstone layers, somewhat banded	5′	0″
5.	Rather massive layers of sandstone interbedded with some shale. The massive layers are more or less concretionary	5′	0″
4.	Soft arenaceous shale containing some concretions	6′	8″
3.	Layer of massive concretions more or less continuous, but sometimes interrupted and apparently somewhat replaced by the bluish shale	3′	0″
Bedford shale.			
2.	Bluish gray shale, which is rather argillaceous, but somewhat gritty	2′	0″
1.	Covered to level of Big Walnut Creek	5′	0″

The Berea grit has been quarried to some extent along the banks of this creek, however it is worth but little for commercial purposes.

Sunbury Shale.—The disappearance of the sandy sediments is no less remarkable than it is sudden. Few horizons are more marked than is the contact between the Berea grit and the Sunbury shale. So sharp is this line that we may be absolutely certain, within a fraction of an inch, where one leaves off and the other begins. The Sunbury is a black argillaceous shale with much bituminous matter resembling somewhat, in general appearance, the Ohio shale. However, it is thinner bedded, more fissile and resists weathering less than does the Ohio. The lower layers of this shale cling with wonderful tenacity to the top of the Berea grit. So often is this the case that large areas exist with but a few inches of black shale separating the sandstone from the glacial drift above. The lower six or eight inches of the Sunbury shale are often quite fossiliferous, although the number of species is small. The most numerous of these fossils are *Lingula melie* and *Orbiculoidea newberryi*, which will be recognized as such genera as are usually associated

with black shale conditions. The great body of the deposit, however, is essentially non-fossiliferous.

Prof. Hicks' typical locality for the Sunbury shale is along Rattlesnake Creek[1] east of Sunbury. Much better outcrops, however, occur along Rocky Fork northeast of Gahanna and especially in Dutch Hollow at Lithopolis. Some of these sections have already been given while that of this latter place will be given in connection with the following formation.

Cuyahoga Formation.—In all sections where the contact between the Sunbury shale and the Cuyahoga formation is exposed, the latter begins with about five feet of bluish gray argillaceous shale. This is followed by fine grained sandstones alternating with shales and all usually bluish in color. In the southern part of the State several of the persistent sandstone layers have received definite names, viz.: Buena Vista stone[2] and City Ledge.[3] Dr. Prosser has revived these names and applied them to their equivalents[4] in central Ohio. He calls the lower fifty feet of the Cuyahoga formation the Buena Vista stone and states that the lowest sandstone of the formation apparently corresponds to the stratum termed the "City Ledge" in southern Ohio. No fossils, other than fragments of plants, and vermicular markings were found in these shales and sandstones, although at some localities in the northern and southern parts of the state very considerable collections of animal remains have been made from it.

The following section was measured along the little run in Dutch Hollow (see Plate XVII) at Lithopolis.[5] It begins near the eight-hundred-foot contour line, three-quarters of a mile northwest of the covered bridge, and runs up stream for a distance of a mile.

Cuyahoga formation.		Thickness.	
10.	Several fairly even compact layers of grayish sandstone, followed in ascending order by bands of arenaceous gray shale and soft uneven sandstone layers to the crest of the hill at the Lyndecker quarry. The shales contain fragments of plants, but no other fossils were found in these layers	31′	0″
9.	Compact even grained blue freestone. This is the only layer of sandstone extensively worked in the quarry, where it is said to extend for hundreds of feet without a cross joint	4′	0″
8.	Layers of sandstone interbedded with shales and thin shaly sandstones outcropping above the covered bridge and along the steep bank below	31′	0″
7.	Massive layer of blue, but frequently iron-stained sandstone.	2′	0″
6.	Arenaceous gray shales and thin layers of blue sandstone	4′	2″
5.	A massive layer of iron-stained blue sandstone, the "City Ledge"	2′	9″
4.	Very soft gray shale composing the base of the formation, wherever this part has been found outcropping	5′	0″

[1] Am. Jour. Sci., 3rd Ser., Vol. 16, 1878, p. 216.
[2] Orton, Edward, Geol. Surv. Ohio, Vol. 2, pt. 1, 1874, p. 626.
[3] Idem, 2nd Ann. Rept., 1838, pp. 263, 264.
[4] Am. Geol., Vol. 34, 1904, pp. 337, 341, foot note.
[5] For a more detailed account of this section and also of other sections in this vicinity, see Prosser, C. S., on "The Waverly Formations of Central Ohio." Am. Geol., Vol. 34, 1904, pp. 335-361.

View of the lower portion of the Cyahoga formation at Lithopolis.

	Thickness.
Sunbury shale.	
3. Fissile black shale in very thin laminae and considerably iron stained in old exposures. Near the outcrop of the Berea grit this shale rises fifteen feet in the south bank of the run. In the north bank, a little farther up-stream, is another fifteen-foot bank capped by the bluish gray shales of No. 4. The characteristic fossils of the base of the Sunbury shale—*Lingula melie* and *Orbiculoidea newberryi*—were found at this place........	26′ 0″
Berea grit.	
2. Fairly coarse grained gray sandstone occurring in the bed of the run and in the bank at the lower end of the out-crop. Layers thick, compact and with no intercalated shale. The upper part of the exposure is in contact with the black shale of the next succeeding division of the section, and is strongly impregnated with iron pyrites, which occurs in small nodules or concretions. Ripple-marked	5′ 0″
Bedford shale.	
1. Soft argillaceous shale, drab in color, but stained yellow where weathered..................................	8′ 0″

The shales of the Cuyahoga formation frequently contain flat iron-stone concretions and occasionally other concretions in which fossils have been found.

Black Hand Formation.—Only a very small portion of the area here discussed is covered by the Black Hand formation. This is the hilly region about two miles east of Lithopolis and known as Chestnut Ridge. The formation consists of soft, coarse grained sandstones which vary in color from yellow or buff to brown and red. It is frequently cross-bedded and often very massive. Occasionally the rock contains a number of quartz pebbles. Portions of the formation contain some fossils, but none were found in the region under consideration.

Chestnut Ridge forms the most conspicuous feature of the landscape in a region of uniformly low relief. Its topography at once suggests interesting geological features and the expectation is by no means disappointed, for this ridge proves to be composed of the very coarse massive yellow sandstone which constitutes the base of the formation so extensively developed in the Hocking Valley, ten miles to the east. These hills are therefore geologically and topographically the outliers of the picturesquely eroded region that gives to the Hocking Valley its beautiful scenery, and owe their existence to the greater resistance to weathering and erosion, of the formation which caps them.

The region about Jefferson affords a clue to the geology of the ridge. One and one-half miles northwest of this village, twenty feet of red Bedford shale overlain by Berea grit is exposed in the south bank of Little Walnut Creek at the covered bridge. The Sunbury shale and the lower part of the Cuyahoga formation are not exposed nearer than Lithopolis. At the north end of Chestnut Ridge, at the southern edge

of Jefferson, the upper Cuyahoga shales and thin sandstones are exposed to within forty or fifty feet of the coarse yellow sandstone capping the ridge. A section at this point follows:

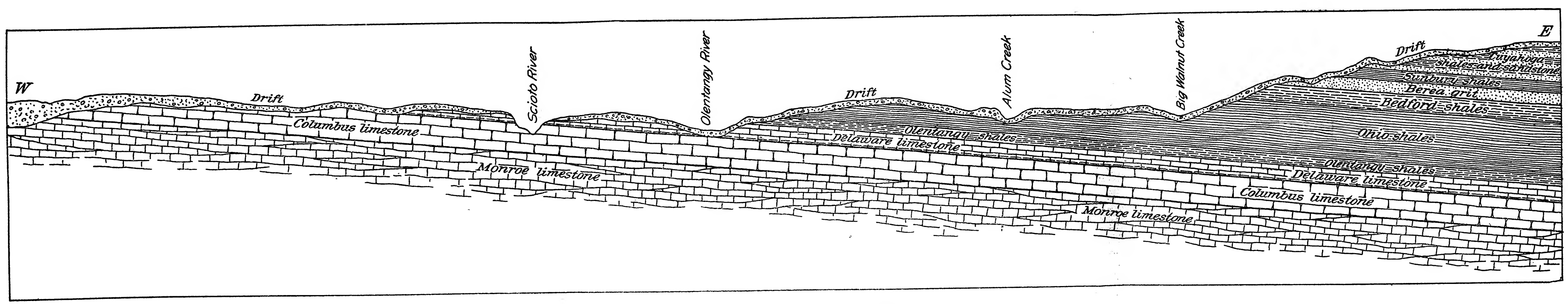
		Thickness.	
Black Hand formation.			
4.	Massive thick bedded, very coarse grained, soft yellow sandstone in the quarry at the north end of the ridge. The whole rock is apt to be impregnated with iron in irregular bands and concretions. At some places these layers are colored various shades of red or brown, while other bands are entirely without coloring matter.	40′	0″
3.	Covered interval	50′	0″
Cuyahoga formation.			
2.	Thin bedded sandstones and shales, bluish at the base of the exposure, becoming more iron stained and somewhat coarser towards the top	60′	0″
1.	Covered to road level at Jefferson	5′	0″

On the crest of the ridge, nearly a mile south of the village of Jefferson, is an old abandoned quarry in the more massive layers of the upper part of this coarse sandstone. It was from this place that the massive stone was obtained, years ago, for the canal locks of the vicinity. The sandstones of Chestnut Ridge resemble closely the quarry beds south of Newark and about Lancaster, but perhaps the latter more closely since it is not so fine grained as the Newark stone. Eastward this coarse sandstone can be traced almost continuously to the vicinity of Lancaster and there can be no doubt that it forms the western-most outcrop of the formation so well developed at that place. Stratigraphically, the Black Hand is the highest formation, except the glacial drift, of this area and forms thus the last feature of consideration, the drift being treated in connection with the physiographic discussion of the area.

LIFE RECORD.

In many of the stratified rocks are to be found organic remains, which have previously been referred to as fossils. These give us a knowledge of the life which lived in the seas during the time of the deposition of these sediments and also afford a means by which the deposits, wherever found, may be identified. So universally is it recognized that certain types of life were characteristic of the time during which certain formations were being deposited, that we have come to rely upon fossils for the recognition of the strata of the entire sedimentary record.

Monroe Limestone.—(Plate XIX). The fossils found in the Monroe limestone are not usually abundant. In the region where these strata outcrop along the western side of the quadrangle in question, *Leperditia alta*, a small bivalve Crustacean, is sometimes rather plentiful. *Spirifer vanuxemi* has occasionally been found. This *Spirifer* shows the



A section of the bed rock along a line drawn through Columbus from west to east.
Horizontal scale, one inch equals two miles; vertical scale, one inch equals 660 feet.

simple plications characteristic of the early forms of the genus. In the northern part of the state fossils are frequently quite abundant in the Monroe and the number of species is considerably increased. These fossiliferous strata of the Monroe are quite extensively developed in Ontario and southeastern Michigan,[1] where they have received considerable attention of late.

Columbus Limestone.—(Plates XIX-XXII.) The Columbus limestone has by far the largest fauna of any of the formations outcropping in this region. Corals, brachiopods, mollusks and even fishes are abundant in nearly every outcrop, while at places, such as Harrisburg, the layers are literally crowded with certain of them. This rich fauna, following so closely on the relatively unfossiliferous strata of the Silurian, places this formation in marked contrast to the Monroe. Coral beds of reef-like dimensions are common along the Scioto River, especially about 65 feet below the top of the formation. These are made up largely of the compound forms, such as *Favosites emmonsi*, *Syringopora tabulata*, *Synaptophyllum simcoense*, etc.

Brachiopods are abundant throughout the Columbus limestone. The brachiopod, it may be said, has a two-valve shell as does also the pelecypod or common clam. The shell of the former may be distinguished from that of the latter, however, by the fact that it is bi-laterally symmetrical. That is, if a line be drawn from the beak or point of the shell to the middle of the opposite margin, it divides the shell into two equal parts which are symmetrical about this line. Of the brachiopods in the Columbus limestone, the most interesting are the *Spirifers*. They range from the type with simple costae as in *Spirifer duodenarius* to *Spirifer acuminatus* with its bifurcating costae and finally *Spirifer divaricatus* in which the costae bifurcate and the fold and sinus are also covered with costae. These progressive developmental characters of the *Spirifer* culminate in *Spirifer cameratus* of the Pennsylvanian, where the whole shell is covered with secondary bifurcating costae. Another interesting form is the genus *Chonetes*. This genus, which is represented by three species in the Silurian where it makes its first appearance, has thirty species in the Devonian. The most common form is *Chonetes mucronatus*. The distinctive characteristic of *Chonetes* is the row of spines along the upper margin of the cardinal area and often appearing as though they extended along the hinge line. The genus *Productella* was introduced in the Devonian and may be considered as the forerunner of *Productus*, which came in during the Mississippian. It has the gibbous pedicle valve and spiny surface of the *Productus*, but differs from the latter in that it has teeth on its hinge line.

Among the mollusks, the pelecypods are not especially common but

[1] See Grabau, A. W., and Sherzer, W. H., Mich. Geol. and Biol. Surv. Pub. 2, Geol. Ser. 1, 1910.

they are rather distinctive. *Paracyclas elliptica* and *Conocardium cuneus* are the more common. Gastropods are quite abundant, especially in the cherty layers above the coral zone. These often have the external markings well preserved. *Platyceras dumosum* is almost always to be found a few feet below the "bone-bed." Cephalopods occur more or less frequently throughout the formation. The large coiled form, *Ryticeras cyclops*, is sometimes fairly common in the middle portion of the formation.

The pygidia or tails of trilobites are to be found occasionally and the heads more rarely. These belong to a half dozen or so genera, of which the more common are figured on the plates herewith. Fish remains are usually limited to the teeth, spines and fragments of the dermal plates. But occasionally the jaws with the teeth in place are found and even at times the whole cranial covering may occur as a fossil. These latter are so conspicuous that they are noticed and collected even by workmen in the quarries.

Delaware Limestone.—(Plate XXIII.) The fossils of the Delaware limestone differ from those of the preceding chiefly in the fewer number of species and in the less abundance of those that do occur. There is, however, the introduction of certain species which occur in more recent rocks in New York State. These come in with the beginning of the formation when such a characteristic Marcellus species as *Leiorhynchus limitare* is introduced into the basal shaly layers. Some of the other conspicuous forms which do not occur below the "bone-bed" are *Delthyris consobrina*, *Chonetes deflectus*, *Martinia maia*, *Grammysia bisulcata*, etc.

Olentangy Shale.—The Olentangy shale has yielded but few fossils near Columbus. One or two fragmentary fossil shells and some fish teeth in the basal portion constitute nearly the whole fauna. At Delaware, however, a small but thrifty crinoid bed was found.

Ohio Shale.—The fossils of the Ohio shale are rare and often inconspicuous. Those usually found are leaves or fragments of plants and their spore cases. A few fish bones and conodont teeth have also been found in the formation.

Waverlyan Series.—(Plate XXIV) Within the area here under consideration the only horizons found to be fossiliferous are the base of the Bedford shale and the base of the Sunbury shale. The most conspicuous fossils of the latter horizon are *Orbiculoidea newberryi* and *Lingula melie*. In the former, or base of the Bedford shale, the fauna is quite large and varied; unfortunately, however, it is still but little known as some of the species have possibly never been described. The relationships and sudden appearance of this fauna have been discussed in the preceding pages. *Palaeoneilo bedfordensis* is one of the common

fossils. Every Waverlyan formation has yielded fossils at some point within the state. The Cuyahoga perhaps contains the larger fauna and especially is this true in the northern part of the state. The plate of Waverlyan fossils here given illustrates species collected in that section and mostly from the Cuyahoga formation. It is intended mainly to represent the Waverlyan fauna in contrast to that of the preceding formations. The introduction of *Productus* and *Syringothyris* is significant of the Mississippian age.

EXPLANATIONS OF PLATES.[1]

PLATE XIX.

MONROE LIMESTONE FOSSILS.

Brachiopods.

Fig. 1. *Meristella bella* Hall.

Figs. 2,3. *Spirifer vanuxemi* Hall. Note the simple plications and the un-plicated fold and sinus. These are characteristics of early Spirifers.

Crustaceans.

Fig. 4. *Leperditia alta* Conrad. This is the more common fossil. It often looks like a small pebble in the rock.

COLUMBUS LIMESTONE FOSSILS.

Corals.

Fig. 5. *Heliophyllum corniculum* (Lesueur). This is one of the simple Corals. It is sometimes called a cup or horn Coral, because of its shape. It occurs throughout the formation, but is probably more abundant in the upper part.

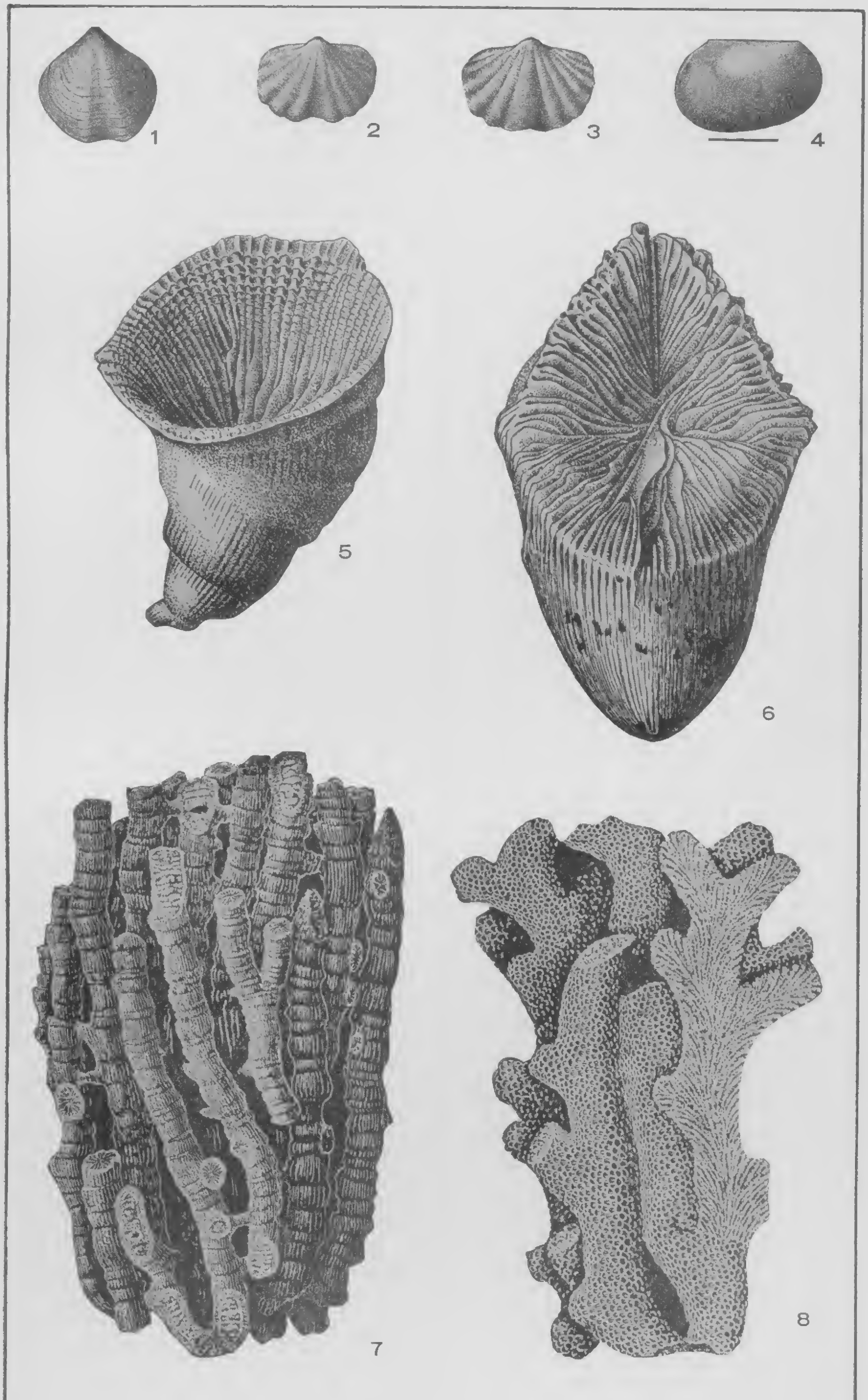
Fig. 6. *Aulacophyllum sulcatum* (d'Orbigny). This is another of the simple Corals. Compare the septae (divisions on the inside) with those of the preceding.

Fig. 7. *Synaptophyllum simcoense* (Billings). One of the common compound Corals. It is made up of a number of individuals growing in a colony.

Fig. 8. *Favosites limitaris* Rominger. Another of the compound Corals.

[1] The illustrations of fossils used in this bulletin are chiefly after Hall, and from earlier reports by the Ohio survey.

PLATE XIX.



Monroe and Columbus limestone fossils.

PLATE XX.

COLUMBUS LIMESTONE FOSSILS—Continued.

Brachiopods. Figs. 1–19.

Figs. 1, 2. *Schizophoria propinque* Hall.

Figs. 3, 4. *Stropheodonta perplana* (Conrad.)

Figs. 5, 6. *Productella spinulicosta* Hall. Usually this fossil shows long spines projecting from the surface. This genus differs from Productus of the later formations, in that it has hinge teeth. The genus makes its first appearance in the Middle Devonian.

Fig. 7. *Stropheodonta hemispherica* Hall.

Fig. 8. *Reticularia fimbriata* (Conrad). The fimbriate structure shows up nicely under a magnifying glass.

Figs. 9, 10. *Chonetes mucronatus* Hall. Note the spines projecting from the pedicle valve along the upper margin of the cardinal area.

Fig. 11. *Atrypa reticularis* (Linnaeus).

Fig. 12. *Pholidostrophia iowaensis* (Owen).

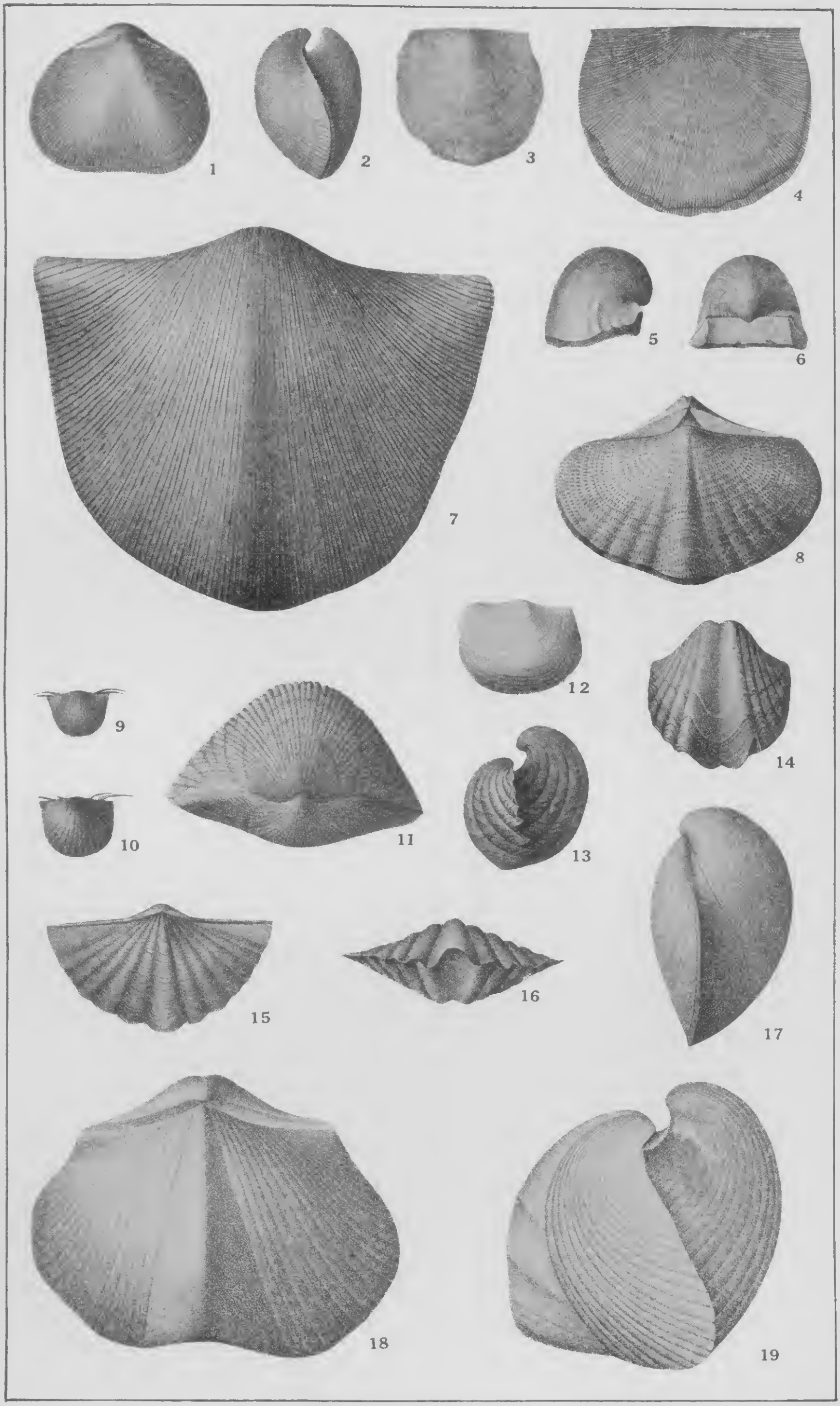
Figs. 13, 14. *Spirifer gregarius* Clapp. A common fossil in this formation. About thirty-two feet below the "bone-bed," it occurs in great numbers.

Figs. 15, 16. *Spirifer duodenarius* (Hall). This fossil occurs only in the upper part of the formation in central Ohio. It, as also the preceding, belongs to the primitive simple plication type of Spirifer.

Fig. 17. *Meristella nasuta* (Conrad). A smooth spire-bearing shell, which occurs most abundantly in the lower part of the chert zone.

Figs. 18, 19. *Spirifer acuminatus* (Conrad). This Spirifer is almost entirely limited to the upper part of the formation in the region here discussed. Note that its costae or ribs bifurcate, a characteristic of the more advanced species of the genus.

PLATE XX.



Columbus limestone fossils.

PLATE XXI.

COLUMBUS LIMESTONE FOSSILS—Continued.

Pelecypods. Figs. 1-5.

Fig. 1. *Paracyclas elliptica* Hall. This is a common and easily recognized fossil, occurring throughout the formation.

Fig. 2. *Conocardium cuneus* (Canrad). This fossil usually occurs as merely a cast of the interior of the shell. It is one of the most striking fossils of the formation.

Fig. 3 *Modiomorpha concentrica* (Conrad). Note the concentric marking of the surface, which has given the specific name.

Fig. 4. *Aviculopecten cleon* Hall.

Fig. 5. *Mytilarca percarinata* Whitfield. This is not a common, but a very characteristic fossil.

Gastropods. Figs. 6–11.

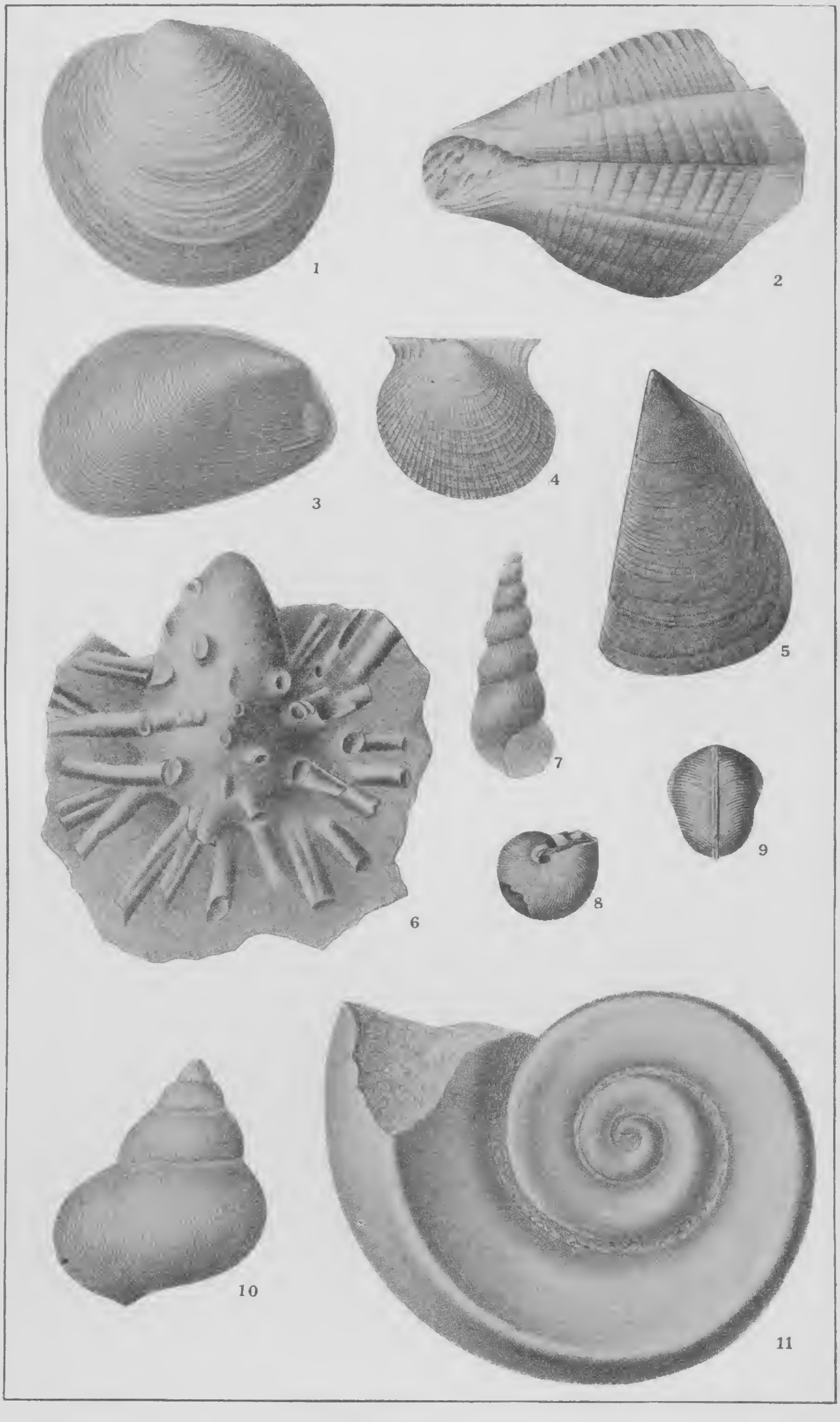
Fig. 6. *Platyceras dumosum* Conrad. Note especially the spines which cover the exterior part of the shell. It is a common fossil just below the "bone-bed."

Fig. 7. *Loxonema pexatum* Hall.

Figs. 8, 9. *Bellerophon pelops* Hall. Note that this shell is coiled in a single plane. Usually found as a cast of the interior.

Fig. 10. *Callonema bellatulum* (Hall). These last three are excellently preserved in the cherty layers of the Columbus limestone. Even the smallest exterior markings of the shell show nicely.

Fig. 11. *Pleuronotus decewi* (Billings). A very common cast in this formation. It is rarely preserved with the shell, and yet it is quite readily recognized. The coil is nearly in a single plane.



Columbus limestone fossils.

PLATE XXII.

COLUMBUS LIMESTONE FOSSILS—Continued.

Pteropod.

Fig. 1. *Coleolus crenatocinctus* Hall.

Cephalopod.

Fig. 2. *Spyroceras thoas* Hall. One of the straight Orthoceratites, which are quite abundant in some parts of the formation.

Crustaceans (Trilobites). Figs. 3–7.

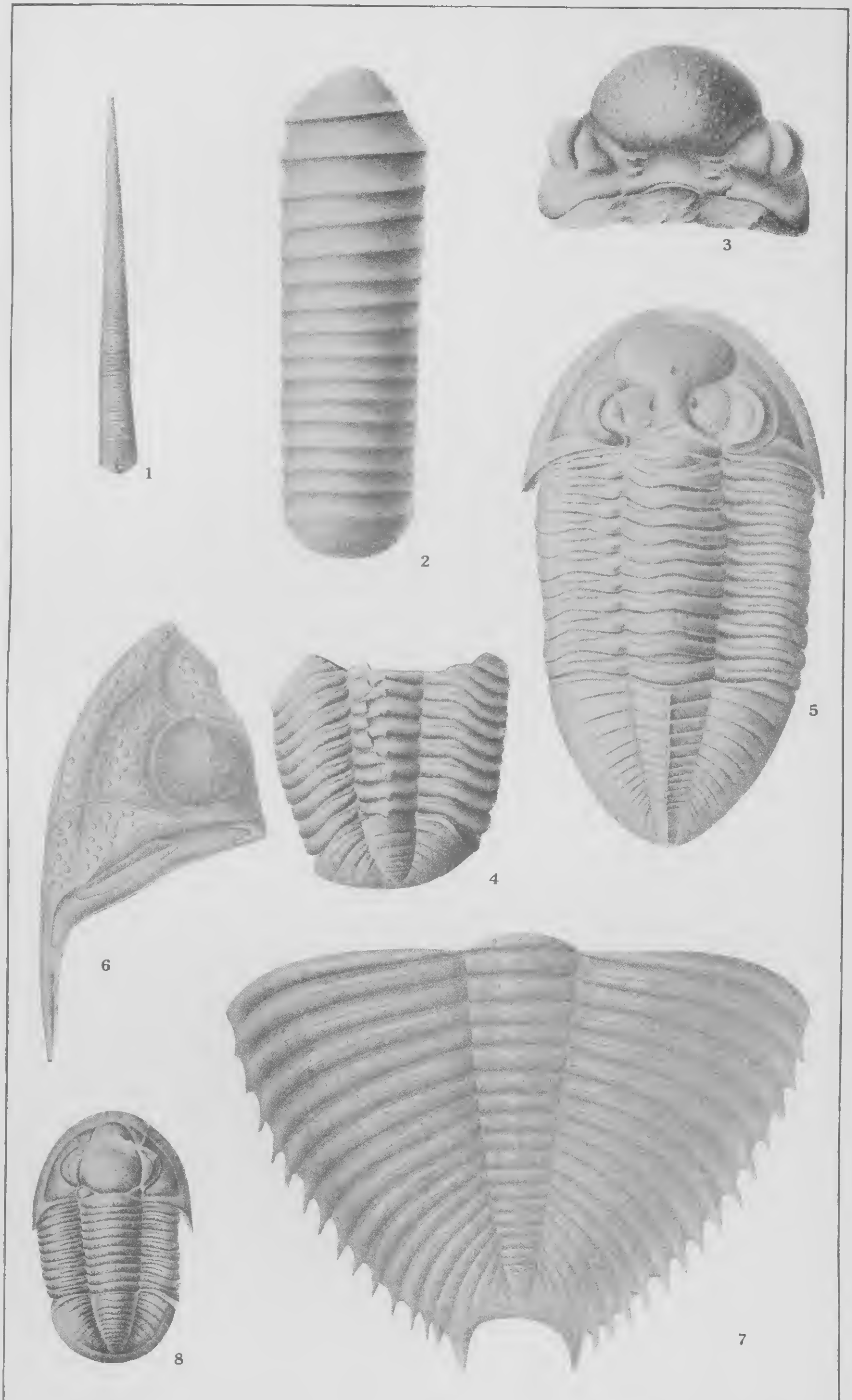
Figs. 3, 4. *Phacops cristata* Hall. Usually it is only the pygidium of the trilobite that is found. The four species figured on this plate are quite common.

Fig. 5. *Chasmops calypso* Hall.

Figs. 6, 7. *Coronura diurus* (Green).

Fig. 8. *Proetus rowii* (Green).

PLATE XXII.



Columbus limestone fossils.

PLATE XXIII.

DELAWARE LIMESTONE FOSSILS.

Brachiopods. Figs. 1–17.

Figs. 1, 2. *Orbiculoidea lodiensis* (Vanuxem).

Fig. 3. *Lingula manni* Hall. These two fossils occur in the shaly basal portion of the formation. Their shells are composed of phosphate of lime, as is so frequently the case in shells occurring in black shale.

Fig. 4. *Lingula ligea* Hall.

Fig. 5. *Rhipidomella vanuxemi* Hall.

Fig. 6. *Stropheodonta demissa* (Conrad).

Figs. 7, 8. *Leiorhynchus limitare* (Vanuxem). This is a characteristic fossil of the Marcellus shale.

Fig. 9. *Leptaena rhomboidalis* (Wilckens). This species, as at present defined, is one of the long-lived forms. It is found from the Trenton to the Waverly, but there is a difference in the forms from the two extreme ends. These, however, seem to grade into each other.

Figs. 10, 11. *Delthyris consobrina* (d'Orbigny). A common fossil of the formation. Note the zigzag concentric markings; unfortunately, these seldom show in specimens from the limestone

Figs. 12, 13. *Martinia maia* (Billings).

Figs. 14, 15. *Chonetes deflectus* Hall. Compare this with the *Chonetes* figured among the Columbus limestone fossils.

Figs. 16, 17. *Cyrtina hamiltonensis* Hall.

Pelecypods. Figs. 18 and 19.

Fig. 18. *Pterinea flabellum* (Conrad).

Fig. 19. *Grammysia bisulcata* (Conrad). Note the ridge, with a furrow on either side, running from the beak to the margin.

Gastropods. Figs. 20 and 21.

Figs. 20, 21. *Platyceras erectum* (Hall). Compare this species with the spiny one occurring in the Columbus limestone.

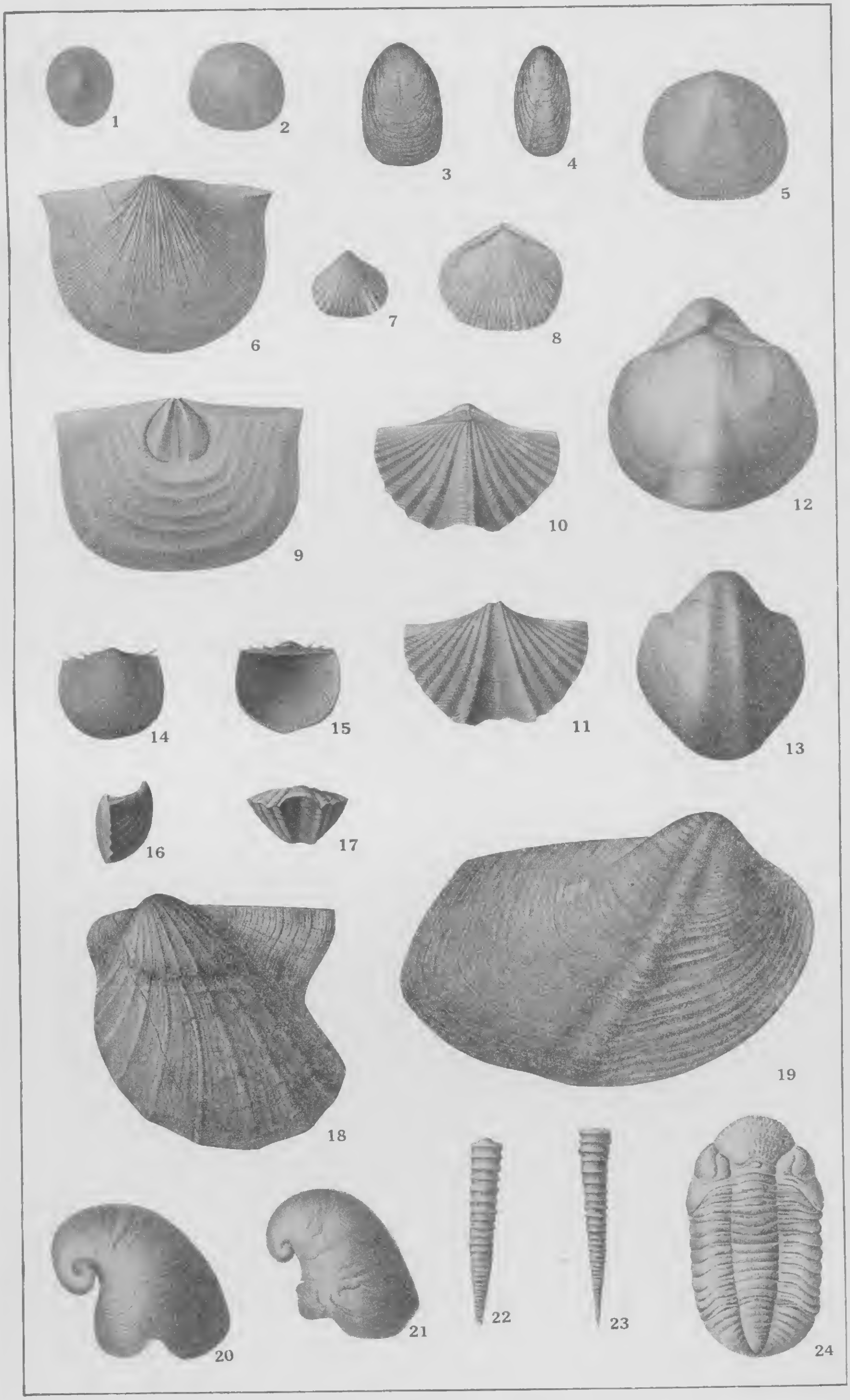
Pteropod. Figs. 22 and 23.

Figs. 22, 23. *Tentaculites scalariformis* Hall. This fossil is very frequent and readily recognizable. It is probably a worm tube.

Crustacean (Trilobite). Fig. 24.

Fig. 24. *Phacops rana* (Green).

PLATE XXIII.



Delaware limestone fossils.

1000—G. B. 14.

PLATE XXIV.

WAVERLYAN FOSSILS.

Crinoid. Fig. 1.

Fig. 1. *Platycrinus lodensis* Hall and Whitfield. Crinoids are among the abundant fossils of the Mississippian, especially in the west.

Brachiopods. Figs. 2–9.

Figs. 2, 3. *Orbiculoidea newberryi* (Hall).
Fig. 4. *Lingula melie* Hall.
Fig. 5. *Orthothetes crenistriata* (Phillips).
Figs. 6, 7. *Athyris lamellosa* (L'Eveillé).
Fig. 8. *Syringothyris carteri* (Hall).
Fig. 9. *Productus semireticulatus* (Martin).

Pelecypods. Figs. 10–13.

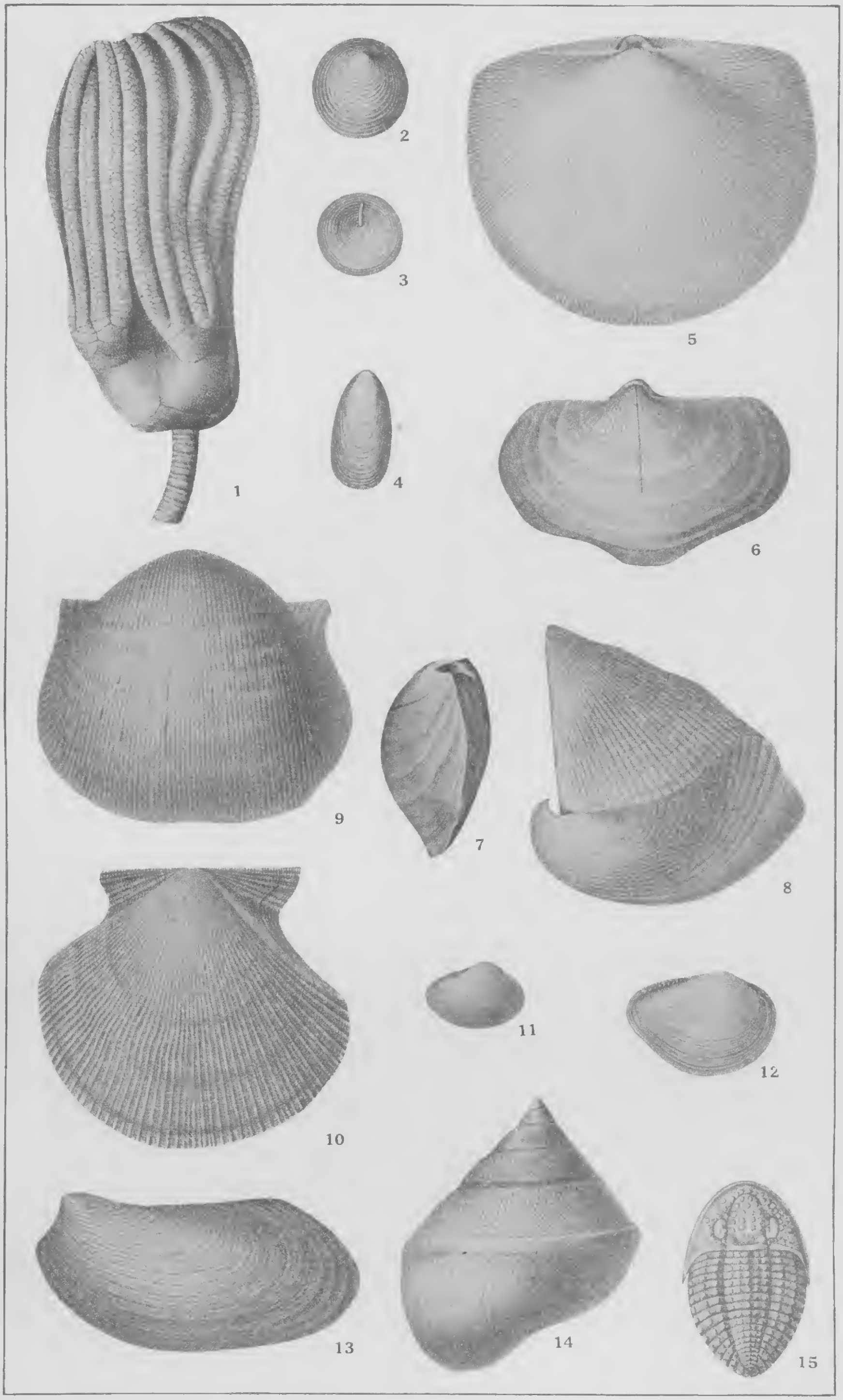
Fig. 10. *Aviculopecten winchelli* (Meek).
Figs. 11, 12. *Palaeoneilo bedfordensis* Meek.
Fig. 13. *Allorisma winchelli* Meek.

Gastropod. Fig. 14.

Fig. 14. *Mourlonia mississippiensis* (Wh. and Whit)

Crustacean (Trilobite). Fig. 15.

Fig. 15. *Phillipsia lodiensis* Meek.



Waverlyan fossils.

PART II.

PHYSIOGRAPHY OR SURFICIAL GEOLOGY.

By GEORGE D. HUBBARD

CHAPTER II.

LOCATION.

Physiographically the area around Columbus included within the scope of this bulletin belongs to that regional province known as the Prairies. Nevertheless, the topography of the region lacks the variety of feature, the rolling surface with sag and swell or with hillock and kettle containing swamp or lake, so constant over broad reaches of these drift prairies. In the early days it differed from much of the prairies in being rather completely timbered. Further, the area is located near the eastern border of the prairies, so near in fact that the southeastern corner comprising some twenty-five square miles, shows the effects of the more resistant rocks of the Allegheny Plateau, and presents rock hills. A similar effect, in higher land but not hilly, is found continuously from Pickerington northward to the limits of the area, in a belt four miles wide at Reynoldsburg and over seven miles wide at New Albany. The highest of this land is about two hundred feet above that lying to the west with well-marked west-facing slopes and occasional bare "brows" of rock between, but no escarpments.

The drift border lies nearest to Columbus on the southeast. While the area lies from fifteen to sixty miles northwest from the drift margin, it is near enough to be in the zone of thick accumulation, and it has received a heavy mantle of till transported by the continental glaciers of the recent ice age from many points to the north, even as far as Canada. With this great depositional work, probably, as may be shown later, very little ice erosion was accomplished. While the thickness of the drift varies greatly, its surface is so evenly disposed that aside from one large moraine, almost the whole area may be called a till plain of remarkable levelness, broken only a little by very moderate, postglacial, stream erosion.

GENERAL DESCRIPTION OF TOPOGRAPHY.

The Drainage Pattern.—On the topographic map the most striking feature is the north-south alinement of streams, valleys, and interstream areas. This was noted in one of the earliest descriptions

of Franklin County physiography,[1] and has not ceased to call forth comment. It is perhaps the most perfect part of a similar alinement of streams over several neighboring counties.

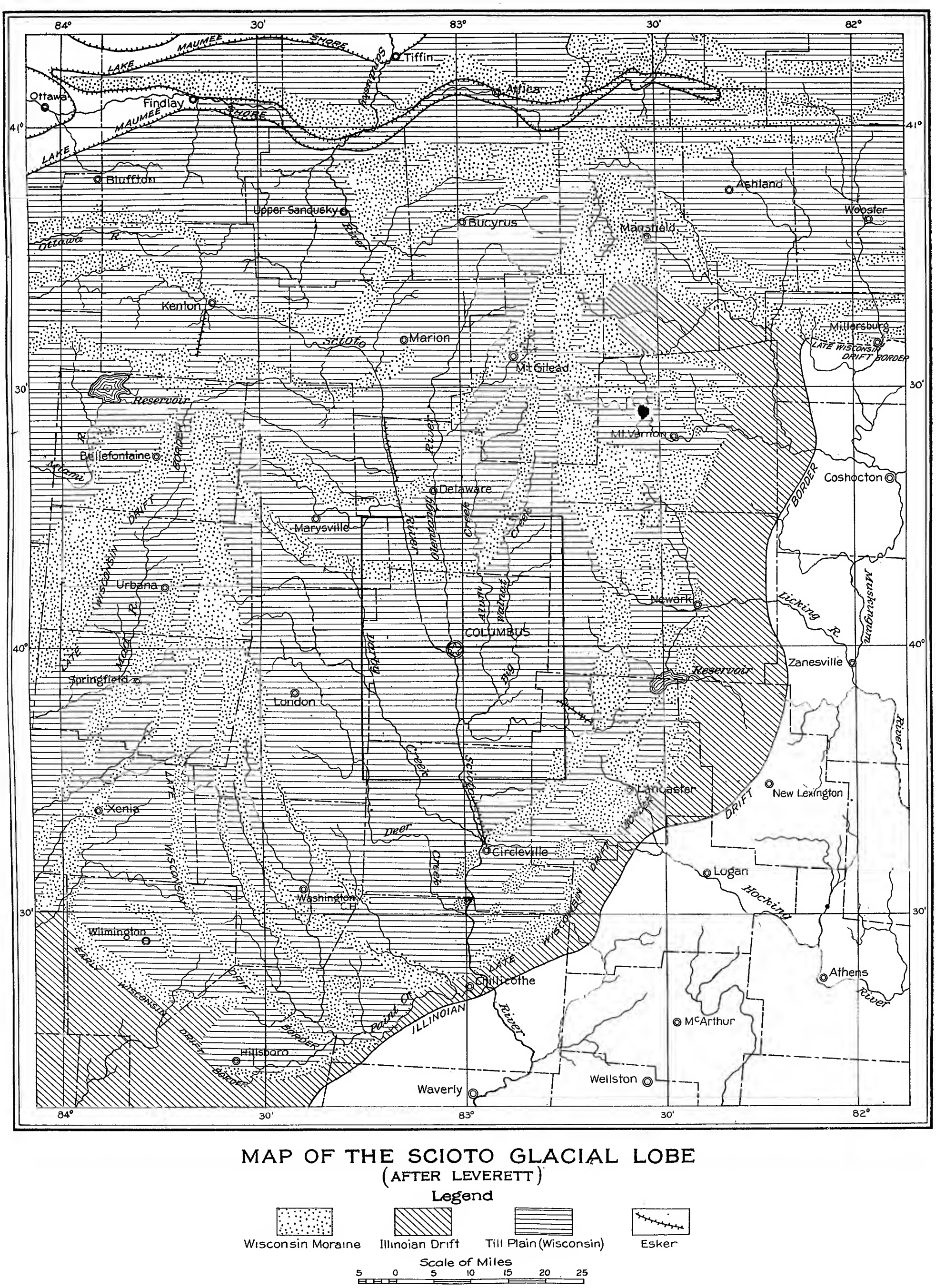
In the northern part of the area there are four, nearly parallel, south-flowing, slightly-converging streams, and two others, one on each side of the four, just beyond the limits of the quadrangle. Between these six streams extend five strips of inter-stream plain. Several of the railroads, in accord with these features, enter Columbus from the north, along these elevated tracts. Adopting the names of small towns upon them, the several level-topped areas between the streams may be designated from west to east as the Hilliards, Powell, Worthington, Westerville and New Albany strips.

In the southern part the alinement shows less clearly. This part is bisected by the Scioto and its western half is, in the main, a continuation of the Hilliards strip; but, owing to the fact that the downstream convergence of the valleys has brought the Darbys within the area, a considerable tract of another strip between them and Deer Creek is included in the quadrangle. Since the Olentangy River enters the Scioto, the Powell strip runs out at their junction. The Worthington strip is cut off at the south by the Big Walnut as it swings westward and joins the Scioto after receiving Alum Creek from the right side and Blacklick from the left. In a similar manner the Westerville strip is terminated southward by the junction of its bounding streams. The New Albany strip, split in its southern part by Blacklick, may be thought of as continuing southwestward beyond the mouths of Alum Creek, Blacklick and Big Walnut off the area, and bounded on the southeast by Little Walnut which cuts around the small, hilly tract in the corner referred to in the first paragraph.

Minor Lateral Valleys.—These major water courses mentioned above are for the most part, consequent streams on the till plain, and they date from the last retreat of the glacier from the region. It will be shown later that none of them can claim, at least to any significant extent, a preglacial ancestry. Many lateral minor valleys, developed by subsequent streams, join each of these major valleys, descending in the northern part as rock gorges from the interstream remnants of the till plain, 100 to 200 feet, to the floors of their masters; but wandering in the southern part as shallow, youthful, drift valleys because here the till plain is much lower with reference to the Scioto than farther north.

The lateral valleys are undoubtedly the most valuable criterion for measuring post-glacial time, because the majors were well under way when the ice was finally melted, having been initiated by the drainage attendant on the melting of the ice. In many of the tributaries of the

[1] Orton, Edward, Geol. Survey of Ohio, vol. 3, pp. 596, 597.



Moraines of the Scioto Valley Lobe. Note the loops festooned from the highlands on either side with till plains between. The Columbus area is located. (After Leverett, Mon. U. S. Geol. Surv., No 41, Pl. XIII.)

Scioto, particularly on the right or western side, are waterfalls over ledges of the heavy-bedded limestone already described as underlying this part of the area.[1]

The Moraine Pattern.—Crossing this conspicuous, approximate parallelism is a weaker but equally significant concentric pattern consisting of purely glacial features. It was stated on a previous page that almost the whole area might be called a till plain. Indeed, it is a part of one of a series of similar crescentic till plains, alternated with a series of concentric recessional moraines, convex toward the south, and festooned across the central part of the State from the highlands near Bellefontaine to those near Mt. Gilead and Mansfield. A clear conception of this concentric arrangement of features can be obtained by consulting the map, (Pl. 25), which is reproduced from Leverett's[2] exhaustive treatise on the glacial features of the Ohio and Erie Basins.

One of the larger moraines shown on this map, and designated the Powell, sweeps across the area from Sunbury and Galena in the northeastern part, southwestward nearly to Westerville, then it bears more nearly westward, where it is crossed by Alum Creek and Olentangy River just north of the Franklin-Delaware county line, and by the Scioto on the same line southwest of Powell. From this point it bears a little northwest in a broad belt to New California and far beyond the confines of the quadrangle. South of this large moraine and somewhat concentric with it, may be traced other much smaller, less continuous, belts of moraine as shown on the physiographic map. (In pocket.)

Glacio-Fluviatile Features.—Associated with these moraines are two types of features. On their convex or southern sides are some minor outwash deposits, and within their concavities are several interesting eskers. Tumuli of till, sand and gravel occur in considerable numbers over parts of the till plain, but they do not in any manner seem to conform to the concentric pattern. A large kame area consisting of a pile of gravel hills about four miles south from the city limits of Columbus, is adorned by the uniformly red and white buildings of the Hartman farm. Several kame areas will be described subsequently with the other glacial features.

Rainfall and Runoff.—Since it is the rainfall which perpetuates the streams and keeps them at their perennial task of reshaping and removing the lands, it may be well here briefly to describe the rainfall and some related topics. The total precipitation in Central Ohio including all rain, hail, sleet and snow, amounts to about 40 inches each year, or enough to make a layer of water all over the area three and one-

[1] Chapter I, p. 209.
[2] Leverett, Frank, Mon. U. S. Geol. Survey No. 41, pl. XIII.

third feet deep. Probably not more than one-third of this runs off; but it is this third which carves the valleys, carries the waste away and delivers it to the larger streams or builds it into such minor features along the valleys as alluvial fans and flood plains.

Of the portion which soaks into the ground, a small part is collected in cracks in the rocks or in more or less porous layers above relatively impervious ones, and thus conducted again to the surface along valley walls, as seepage, or, if the latter be concentrated, as springs forming streams. Most of this water coming out as seepage or springs ultimately gets into the streams, so it assists in erosion and transportation.

A small portion of the water which falls as rain is collected in basins on the surface and thus keeps a few tiny lakes and swamps in existence. If it were not for these basins and for the almost continuous vegetation cover, maintained by the precipitated moisture, a cover which prevents much water from running off, the streams would carry away a much larger proportion of the rainfall and with it much more rock waste, and erosion would certainly be greater. This assumption is on the ground that the precipitation remains the same.

CHAPTER III.

PHYSIOGRAPHIC HISTORY.

PRE-WISCONSIN WORK.

Although to the casual observer practically everything seen in the Columbus quadrangle may seem to date from the melting of the great glacier, the history of the features just described began ages before the time of the coming of the ice, just as American history has its roots far back in the nations of Europe, although the first settlements were made here only 300 to 350 years ago.

The development of the present features depends partly upon the rock structures underneath, and partly upon the treatment those structures have had through millions of years at the hands of weather, glacier, and stream.

For a full and adequate description of the rocks, their origin, position, structure, and strength, the reader is referred to the chapter[1] dealing with the geology of this region. Their modification by the various physiographic agents, from the time they were made, down to the present, in so far as the changes have contributed to the present topography, will now be examined. Some of the record is deeply buried beneath the glacial drift, other parts have been mutilated in bringing about later changes; therefore many points are in obscurity and some are today entirely out of our reach. In some cases the incompleteness of the obtainable record may lead to wrong conclusions, hence great care should be exercised in interpretation.

PREGLACIAL TOPOGRAPHY.

Without endeavoring to present the argument all the way through, it may be stated that the area under discussion had been subjected to subaerial conditions of weathering and stream work from before the close of the Paleozoic era down to the Glacial period. During this time there had been oscillations of level and climatic changes. The land had been roughened by erosion, valleys had been carved, widened and deepened, tributaries developed and divides reduced until the whole region had passed from physiographic youth, through maturity, to old age. This process was probably repeated more or less completely more than once, so that just prior to the coming of the glacier, the country presumably had been reduced from a low plateau to a lower, grandly rolling surface deeply mantled with residual soil and subsoil.

[1] Chapter I.

Evidence in the Field.

The rolling topography of large pattern may be found, modified to some extent by ice erosion, in the large features of the present rock topography. To appreciate it one must necessarily pass over many local steep slopes, which will be treated later, and examine only the general or larger features.

Gentle Slopes.—A few local examples of the slopes referred to under the heading "grandly rolling" will suffice to make the meaning clear. Lithopolis in the southeast lies among the hills. A couple of miles to the east and southeast of this village is Chestnut Ridge, a crest with neighboring hills all of sandstones and sandy shales. The highest rock surface among these hills rises to about 1,150 feet; to the north and west the slopes descend from the crest at the rate of about 100 feet to the mile, and the rock surface drops from this summit altitude to 800 feet in three miles northward, to 750 feet in four miles northwestward, and to 760 feet in five and one-half miles westward. Such slopes make an angle with the horizontal of about one degree.

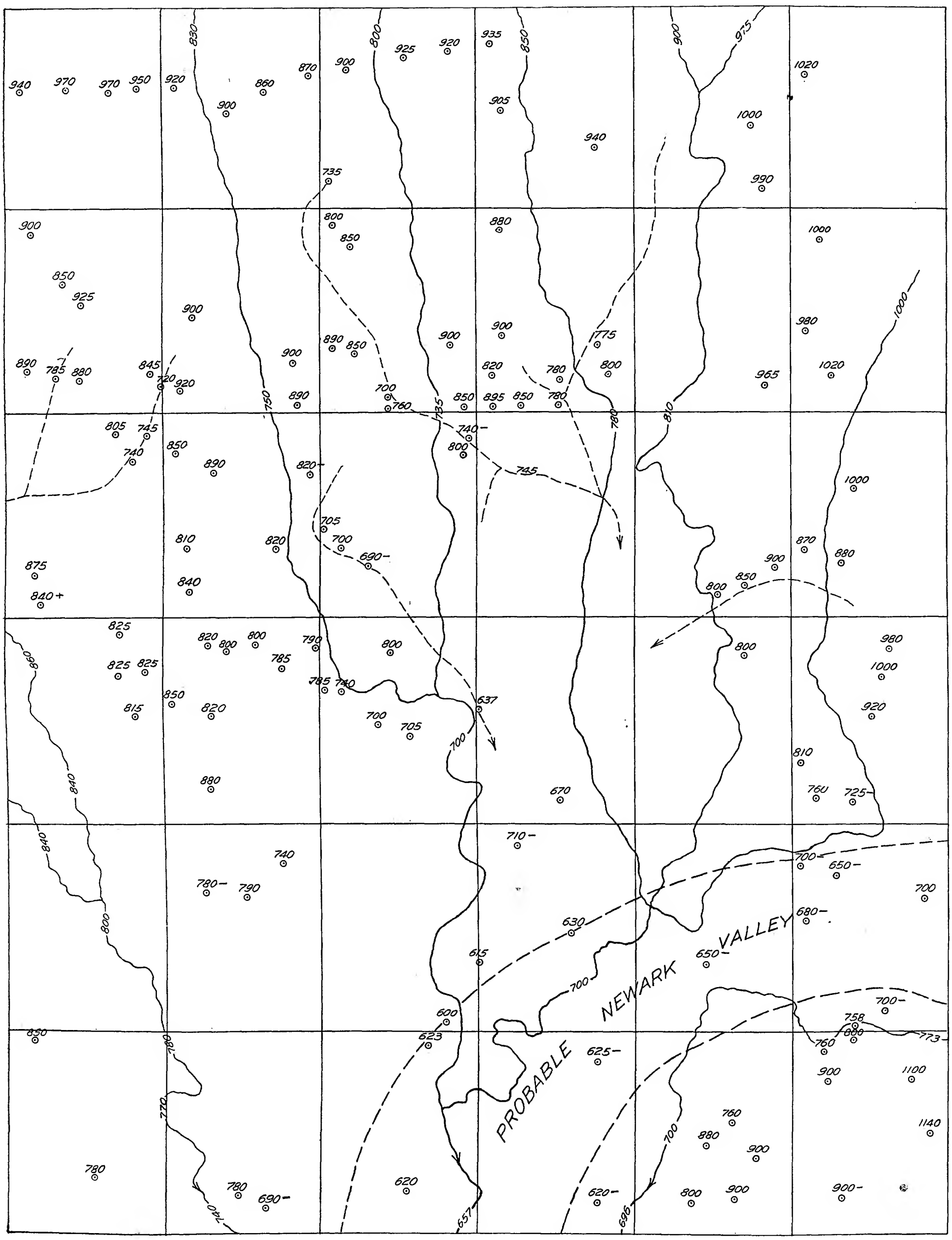
*Other examples from the southwestern part of the area are added. At Derby, wells strike the rock at a depth of 130 feet, which places the rock surface about 780 feet above sea level. (Pl. 26.) Around Harrisburg, the stream has revealed it in several places, ranging from 800 to 780 feet above sea level. Southeast of Harrisburg, some five miles, and one mile southwest of Matville, the rock is less than 690 feet above sea level. A mile nearer Harrisburg, it is 100 feet higher. This lowest altitude is fifty feet below the lowest bed of the channel of Big Darby on the area.

At Rome, on the National Pike, a few miles west of Columbus, the rock surface is 820 feet high and is covered with over 100 feet of drift. Two miles south of Rome, the rock is 880 feet high, while two and three-fourths miles farther southeast toward Grove City, it is only 740 feet above sea level. (Pl. 26.) The Scioto south of Columbus nowhere encounters rock, therefore, all along the river the rock surface is less than 700 feet above sea level, and at the edge of the area less than 660 feet.

Rarely are these slopes of the rock surface as great as 50 feet in a mile, but they are greater than the slopes of the till plain except where it has been modified by post-glacial erosion. Instances with the same values might be multiplied from other parts of the quadrangle.

Steeper Buried Slopes.—Besides these long gentle slopes which must have required ages to make, well records and gorge wall outcrops reveal many ancient, steep rock-slopes and a few valleys comparable with the present steep-sided gorges. Some of the more marked instances found are added. A little over a mile north of Amlin are several wells along the east and west road whose depths make known much of the rock topography. The first one on the west end of the series shows the rock surface to be less than 760 feet above sea level; the next one an

*Text in smaller type consists of additional examples similar to those previously given, or of somewhat elementary matter, which may be familiar to many readers. It is believed that all fine print may be omitted without breaking the continuity of the report.



Rock topography beneath the drift. Figures give the altitude of the rock above sea level for the place indicated by the circle. Solid lines show present major streams and figures in these lines altitude of stream bed regardless of material. Supposed buried valleys shown with broken lines. Probable Newark Valley between two heavy dash lines in southeastern part. Altitudes given with a minus sign are maxima, the rock not having been reached.

eighth of a mile away, and across the road, shows the rock surface at 803 feet, while another about a half mile east shows 845 feet. One-eighth of a mile farther east the rock surface is 720 feet high and less than one-third of a mile still farther east it is 920 feet. Here is a valley less than a half mile wide with an east wall 200 feet high and a west wall of at least 125 feet, with slopes of 1 in 7 or 8, and 1 in 5 respectively (Fig. 11). It is manifest that these cannot belong in the same cycle with the very gentle neighboring slopes, and also that there should be no such slopes and valleys in immediately preglacial topography which had been so long in developing. Their presence testifies to a short erosion period following the long one which antedated the laying of the last drift, and also to only moderate glacial erosion after they were made else they would have been rubbed away.

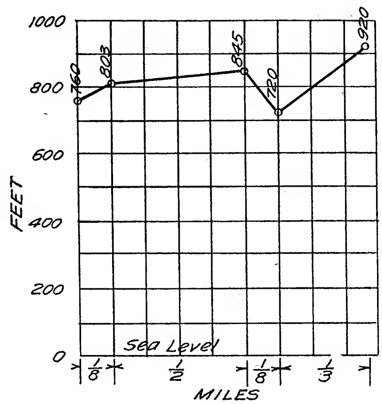


Fig. 11—Section across a buried valley near Amlin. Datum line sea level. Altitudes in feet. Horizontal distance one and one-eighth miles.

Evidence From More Distant Topography.—Further evidence regarding the nature of the preglacial topography of Central Ohio may be had by consulting the topography of southern central Indiana and adjacent parts of Kentucky. Near Tell City, Indiana, and Owensboro, Kentucky, the underlying rock is a series of not very resistant formations, horizontally disposed, and the topography has not been glaciated but the area has been subjected to erosion, as had this of Ohio, through long ages of time and presumably with similar oscillations of level and fluctuations of climate. The slopes are all very gentle, flood plains broad even up the third and fourth order branches; the divides are rows of rolling hills or short, low ridges, rising a hundred feet or a little more above the flood plains. The latter occupy something like half the area. The strongest slopes are 100 feet in about a half mile, but most of them along the divides require a mile or more to make such a descent. There are no gorges nor youthful valleys of any sort. This condition was essentially reached before the glacial period, because there has not been time enough for much change on mature topography since the ice invasion. Such old age as here described must resemble closely in its main features the topography of the Columbus region before the advance of the ice. The steep slopes found may be interglacial, or may be related to the oncoming ice as shown in subsequent pages.

These conclusions as to the character of the immediately preglacial

topography are in harmony with the long period of atmospheric erosion which is known to have continued from the close of the Paleozoic era to the beginnings of the Glacial period.

THE EARLY CONTINENTAL GLACIER AS A PHYSIOGRAPHIC AGENT.

A continental glacier is a large ice cap consisting of snow, modified by pressure and compression, and by repeated partial melting and re-freezing.[1] It usually occurs on a plain or plateau, rather than among mountains, and spreads laterally, overflowing neighboring lands. The thickness is hundreds of feet, and, back some miles from the margin, may be a few thousands of feet. The movement is outward from a central area, approximately radially, but varying in response to topographic irregularities. The margin of these huge ice sheets is usually more or less lobate in response to broad inequalities in the elevation of the land over which they spread.[2] Over broad lowlands between higher, a lobe advances. Forward creeping is much more active on the warmer, or low latitude side, where opposition to advance is perpetually removed by melting. Although the movement is very slow it is very powerful owing to the size and weight, and for this reason a glacial invasion may mean much physiographically to a region.

Repeated advances and retreats (or meltings) of the glacier are believed to have occurred at long intervals over a considerable portion of the North American continent. At least two of these are recorded in Central Ohio which have been called the Illinoian and the Wisconsin.[3]

We have seen in previous paragraphs what manner of topography the ice over-rode on its first invasion of the Columbus quadrangle. The ice sheet entered from the north, presumably in a great rounded scallop known as the Scioto lobe (Pl. 25), and so spread as to occupy the space between the hills near Bellefontaine on the west and the highlands from Mansfield southward to Newark, Carroll and Chillicothe on the east. It may have been so thick as to cover many of these hills at times, and certainly completely covered all intermediate lowlands. Where not over-ridden again by later ice, the presence of old drift would help to determine which hills were covered by the first glacier.

Effects on Plants and Animals.

As the glacier slowly pushed on southward spreading over the broad lowland, it over-rode everything that could not migrate, including of course all plants, trees and forest, bearing them down to the ground and mixing them in with the waste and ground rock which the ice moved forward. All animals which could migrate most likely did so, not as individuals but perhaps as a species through a series of generations. Each generation was more restricted in its roaming on the northern side of its home than was the former, and each new home was placed farther south than that of the year before. There must

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[1] Chamberlin, T. C., and Salisbury, R. D., Geology, vol. 1, pp. 308-317.

[2] Leverett, F., Mon. U. S. Geol. Survey No. 41, pp. 222-226. Carney, F., Jour. Geol., Vol. 15, 1907, pp. 488-495.

[3] Bull. U. S. Geol. Survey No. 58, pp. 14, 15. Leverett, F., Mon. U. S. Geol. Survey, No. 41, pp. 50, 51, 228 f.

have been also a migration of plants. The ice front may be said to have *crept* southward over the area, and possibly with an intermittent advance, interspersed with halts when the melting just equalled the progress of the mass, or with recessions when the melting exceeded the movement forward. But in the aggregate the front of the ice made progress and advanced over the area.

Effects on Streams.

Streams that were flowing away from the glacier would receive water from the melting of the ice and would be increased in size. They would also receive rock waste freed from the melting ice, or washed in by the ice-born drainage. If this waste exceeded the power of the augmented streams to carry, it would be laid along the valleys aggrading until the the stream could carry what was left. It is probable that much gravel and sand was thus laid along the old valleys by the streams of low grade. Many of the deeper well records mention gravel and sand near the bottom. Several such did not strike rock until below the present levels of the streams.

About three miles north of Linden, opposite the country schoolhouse, is a well 145 feet deep, which ended in gravel and sand of a bluish unweathered character, without striking rock at all. The depth reached here is 25 feet below the stream bed in Alum Creek two miles east. A test well for oil was sunk a few years ago in the Alum Creek flood plain at the point referred to above, and rock was struck at a depth of 24 feet below the stream, after passing through gravel. A group of deep wells occurs some three miles west of Clintonville, along the divide between the Scioto and Olentangy rivers, several of which encountered gravel near the bottom. One of these reached a depth of 170 feet and ended in gravel without striking rock. The bottom of this one is 30 feet below the channels of both the Olentangy and the Scioto at the nearest points. These gravel deposits may be some that were laid in the valleys by the waters from the oncoming ice. Old, weathered, and often cemented, gravels are found below the fresh ones along the east bluff of the Scioto in the southern part of Columbus, which are probably to be correlated with those referred to above or with outwash of Illinoian age.

Turning now to streams which were flowing toward the approaching ice it must be seen that their difficulties would be quite different. Their valleys would be filled with waste, and by the ice itself, until flow in the normal direction would become impossible. The water would then accumulate as a long lake in the valley, until its level equalled that of some low divide at the head of the main stream or some tributary, when overflow would begin at the lowest place. Water thus flowing over the col in the divide would lower it at least through the thick mantle, possibly in some places into the rock, and this together with aggradation along the bed of the long lake might make it easier for the stream to continue in its new course than to resume the old one when the ice melted out. If the ice, after interfering with drainage beyond its margin in this way, continued to advance over the reversed

stream and the notched divide, mantling all with drift before or after rounding the features by erosion, it might be difficult to find the old col, the new valley, and the broad, mature preglacial valley. Possibly some of the gorge-like valleys found with old drift in them, and steep slopes with old drift banked against them (p. 246), may have originated in this way. In some instances streams flowing eastward or westward might be modified somewhat as here suggested for north-flowing streams.

That this hypothecated ponding actually did take place within this area is shown in two instances. There are great quantities of lake clays exposed in the Glenmary Run both west of the road on the north side of the stream, and east of the road below the trestle, in the ravine behind the schoolhouse, up the east branch and several of its tributaries, and up the eastern tributary of the north branch, which enters the latter near the north dance hall. Some of these clays are blue with small, button-like, calcareous, clay concretions; others are yellow with ferruginous, clay concretions; both are profusely jointed and in some places quite sandy. The distance across this lake as far as now determined, is at least a half mile north and south and nearly as broad east and west. The sediments rest on the rock at an altitude of 820 feet above sea level near the trestle and their upper surfaces have been seen at as great an altitude as 890 feet, hence the thickness may be assumed to be as great as 60 to 70 feet. In at least three places the characteristic blue, hard, jointed, boulder clay was found above the lake beds which must establish their age as pre-Illinoian. Additional evidence to fix their age is found in a dark soil at one place on top of the old drift, with new drift capping the soil (p. 256). The second example of stratified clays made at this stage was found one-half mile up the run from the sandstone quarry northeast of Reynoldsburg. A tough, plastic, blue clay, carrying many common Pleistocene shells occurs at the water level and shows below water. Its upper surface, two feet above water, is beautifully ripple-marked, and dips gently southeast. Above the clay is two or three feet of blue, hard jointed, pebbly drift containing clay concretions.

A good example of a filled young valley containing old drift is cut across by Rocky Fork a mile and one-half east of Gahanna just beyond the suspension bridge. Here the Bedford shale stops with a strong south or southeast facing slope and old drift may be seen piled against it some fifteen feet high, above which is 25 to 30 feet of later drift, a part of which is stratified. Between the drift and the bed rock is talus of uncemented fragments of Bedford shale without admixture of drift. (Pl. 27A). This steep slope may not have been formed in the manner outlined above but the evidence shows that at least two ice advances have occurred since it was made. A fuller discussion will be given later (p. 259).

Beyond the margin of the ice sheet are found many illustrations of this type of drainage modification, left uncovered and free for careful investigation. Their presence, like that of the outwash, constitutes one of the tests for judging that the region has been approached by a glacier.

Effects on Mantle.

As has been shown this region is believed to have been deeply mantled with residual rock waste in preglacial days. Only one exposure

of residual waste beneath the old drift was found. This particular case occurs in the northwestern part of the quadrangle, in a small run leading eastward from Hyattsville about one-half mile from the station. The section is as follows:

		Feet.
5.	Loose, fresh yellow till........................ (More in the grassed, gentle slope above).	6–8
4.	Blue, hard, jointed till (apparently old—Illinoian).	6
3.	Stratified sand, much weathered; thickness variable	2±
2.	Hard, rusty, jointed dark material without foreign admixture, probably an old soil grading into No. 1..	2
1.	Ohio shale, firm and strong at water, but weathered above; grading into No. 2	2–5

In all other cases when the old drift is found, either it lies on fresh rock or its contact with the rock is covered. Since at least 75 exposures of probable old drift below new have been noted in this area and only in this one exposure was residual waste seen beneath any of them, it would seem that the removal of the mantle by the earlier ice invasion was more complete than that by the last. At several points residual rock waste was found immediately beneath later fresh drift, showing that the later ice erosion was sufficient to remove the old drift but not the old waste down to the rock.

Effects on Rock Topography.

It has long been granted that ice containing tools in the form of pebbles and boulders, has power to erode rock. Moderately loaded ice with thickness to give it sufficient weight, and capable of considerable movement is a very active eroding agent. Probably the most convincing arguments for ice erosion in this sense, which are found in this area are (a) the pulverized but undecayed rock in the drift, (b) the smoothed, striated, grooved or furrowed rock surfaces and (c) the sharp contact between freshly smoothed rock and the drift at almost all points. This last argument means ice erosion enough to remove most of the effects of previous weathering, and was discussed in the last topic.

Undecayed Rock Fragments.—Two simple tests for pulverized rock can be made. First, ground rock fragments can be seen with the lens. Second, a carbonate reaction with hydrochloric acid applied to drift means undecomposed limestone.

Striations.—Observation in the field is the basis for the second argument. Striated and smoothed surfaces are occasionally found. If ever made on any rock beside the limestone, they have been weathered out and are gone. About three miles northwest of Rathbone the harder limestone presents very nice striations whose direction was

determined by means of a compass to be S. 60° to 70° W. They run over a rock ridge summit which rises here almost through the drift and is quarried at several places. At another point on the east bluff of the river nearly opposite the mouth of Hayden's Run are nicely striated surfaces. Again on the west side of the Scioto River between it and the Toledo and Ohio Central railroad just as the latter swings away from the bluff some four miles out from the station, others occur under fresh drift with the direction S. 17° E. The fourth place is a finely exposed surface cleared for quarrying near the southwest edge of the quarries west of the Scioto River and south of the Pennsylvania railroad tracks at Marble Cliff. Here the direction determined was S. 12° E. No corrections are needed, for the line of no magnetic declination passes very close to Columbus. These four localities are believed to be all new ones, and, except the first, agree well with previous finds.

In each of the four cases above, the glacial striations are on solid unweathered limestone surfaces from which all evidence of rock decay had been removed previous to or during the making of the grooves. No weathering adequate to remove or scarcely to weaken them has taken place since their carving.

Solution Cavities in the Rock.—Rather striking contributions to the question of the measure of modification of the local preglacia

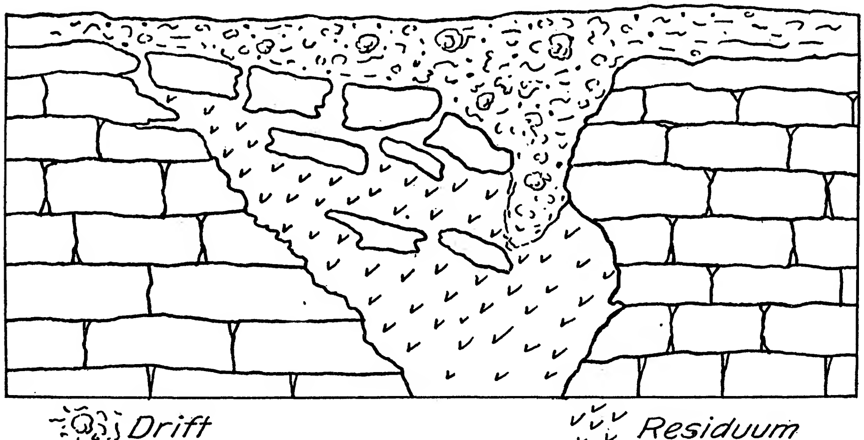

Fig. 12—Tumbled rock due to preglacial weathering. Drift above, and residual chert and clay with no foreign pebbles below. About three and one-half miles west of Union Station, Columbus, and near Scioto River.

topography by ice erosion have been found in a number of the quarries, in the nature of residual clay and chert pockets in solution cavities at considerable depths; and in the multitude of sinkholes and underground water passages on the west side of the Scioto from Marble Cliff northward beyond Rathbone.

In a new quarry south of the highroad along the southern bluff of the Scioto some three and one-half miles west from the State House, the limestone is deeply weathered along joints with considerable residual clay and some chert in the joints and along bedding planes, but always without admixture of any glacial material. So far has the weathering advanced here that the layers have been let down and are a little tumbled and displaced. (Fig. 12.) Farther along the bluff westward and on the north side of the road are several other places where residual clay and chert without glacial fragments occur. At one place a vertical crack six to ten feet wide and twenty feet deep is filled with clay, chert and siliceous corals which have weathered out, but not a fragment of igneous material is intermixed. (Fig. 13.) At another point north of the road a quarry section shows many seams of residual clay and chert and some horizontal bodies in cavities closed by strong rock above, but open below, two to six feet high, and nearly or quite filled with chert and clay. These cavities would have been fair caves when empty.

In the new Casparis quarries west of the Scioto River the work has revealed the fact that the weathering has gone a long distance

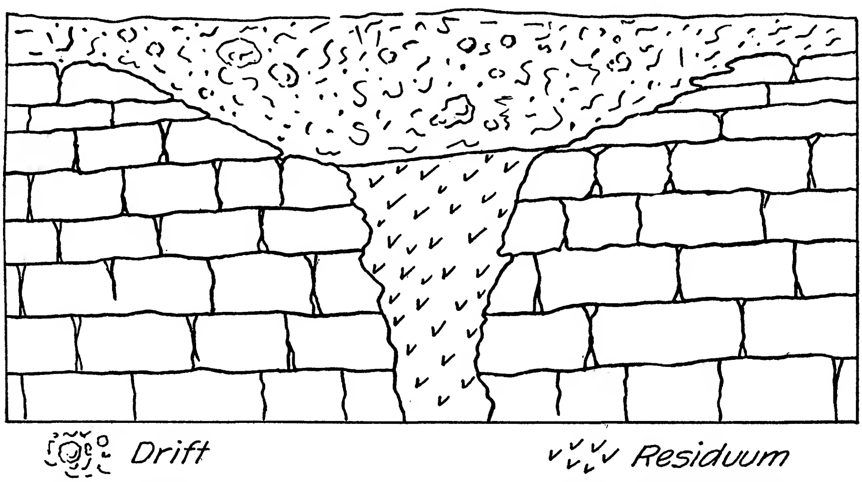

Fig. 13—Crevice in limestone containing residual chert, clay and silicified corals, but no drift. Till above. About three and one-half miles west of Columbus. Near Fig. 12.

below the present rock surface. Along joint planes, solution has removed soluble calcium carbonate and left the clay, an impurity in the limestone, on the walls, thus opening appreciable cracks. These have attained widths as great as two or two and one-half feet, ten or twelve yards below the surface. Along bedding planes further solution has occurred and openings have been made, into which are packed clay and chert from the decomposing limestone. Recently two teams with carts were kept busy some days hauling out this material from a group of pockets in the quarry. The lower pockets thus opened and filled by the work of ground water were at the very base of the excavation, which is fully fifty feet below the rock surface. Here is evidence of extensive and deep weathering. When it occurred cannot be established. Of course, it cannot be postglacial, when the surface of the rock

beneath a few feet of drift retains its striations perfectly. Further, if post-Wisconsin time has not sufficed to efface the striations on the exposed surface, and if, as has been estimated,[1] this period of time is as much as one-seventh to one-ninth as long as that from the Illinoian to the present, it does not seem possible that this deep weathering could have taken place in post-Illinoian time. The point may be made stronger by noting that the older drift seen in so many places is only weathered notably along its joint planes. Another possibility is that there was a still earlier ice invasion, so much earlier that this amount of rock weathering might have occurred since its date. But only two ages of drift have been recognized in Central Ohio. One would necessarily seem to be forced to the conclusion that this weathering preceded the oncoming of the ice. Still further weight may be added to this conclusion, when it is observed that all this deep-lying residual material is absolutely free from foreign pebbles, as it certainly could not be if it had been washed in since the ice had scattered foreign mantle all over the region. This applies whether the Illinoian or some much earlier invasion be the first.

Sinkholes.—From near Dublin, west of the Scioto and eight or nine miles north of Columbus, northward some ten miles may be found many sinkholes. They occur fairly close to the Scioto and also westward a mile or so from the river. They are openings into enlarged joints and cracks; often crevices large enough to admit a man can be entered from the bottom of the sink. Into many of them surface drainage is now poured and by them is led down and away to the river; but they are not to be correlated in formation with the present stream valley, for the cracks are as large leading away from the river as toward it. Such opened joints were found in one of the quarries northwest of Rathbone three miles west from the river, but no sink occurred above, because since the Glacial period, the drainage has not yet found its way through the opened joints and cracks to the river. Similarly enlarged joints were found on the east side of the river in several old quarries; but no sinks occur at the surface on that side except one on the rock terrace two miles above the storage dam where the drift had been removed by the stream. (p. 299). The opened cracks and joints seem to be a common feature of the limestones, but the sink at the surface only occurs where postglacial drainage has been successful in opening passages already existing, downward and away to some drainage line low enough to receive their waters. These passages, since so often not in use now, are certainly preglacial and were more or less obstructed by the glaciers.

Conclusion.—From the presence of the deep weathering found in the quarries, and of the enlarged cracks and joints in many places

[1] Chamberlin, T. C., and Salisbury, R. D., Geology, vol. 3, p. 414

in the limestone, both of which are too extensive and too ancient to have been made since the Glacial period, it may well be inferred that glacial erosion was not deep enough to remove the partly weathered zone over this area. To what depth preglacial weathering had gone, we have no way of knowing, hence, of course, cannot fix the thickness of rock removed, but it is apparent that the glaciers certainly have not scoured off more than a few scores of feet of bed rock after removing the mantle. As was shown above, the Wisconsin sheet probably removed but little beside the mantle and frequently not all of that, while the earlier ice removed more than the last sheet, but only a little bed rock, and that in a manner so as to develop neither uneven nor valleyed topography.

Effects by Deposition.

Beside erosional effects, the glacier must have left its marks as a depositing agent, but this first advance and subsequent retreat could not have been very significant as a factor in present day topography, because the Wisconsin ice sheet over-rode and destroyed many of its features and then deposited new material over the ruins.

The deposition of drift by the earlier ice sheet would stop valleys and cause streams to take new courses and carve new valleys, thus providing the buried gorges which after being filled with later drift are unearthed or cut across by the present streams.

STREAM EROSION IN AN INTERGLACIAL STAGE.

Between the time of the disappearance of the earlier ice sheet and the approach of the later one, streams were busy developing valleys, draining basins, and withal getting possession of the land. These new valleys would not necessarily bear any genetic relation to those existing before the ice came on. They may have coincided with their predecessors in places and crossed them in other places. There should have been a very considerable development of tributary valleys as well. We know but very little of these interglacial valleys.

Buried valleys containing Wisconsin drift have been found in many places. The valley leading westward from Lewis Center to the Olentangy, has a wide section a little over half a mile west of the road and the Columbus, Delaware and Marion electric, and here no rock is found in the valley walls, except at the very bottom. The slopes are all of drift, while both down and upstream from the place, black shale occurs in both bluffs. A half mile south of this run is another in which the rock is entirely wanting for a quarter mile, and only Wisconsin drift occurs in the walls. It looks as if a pre-Wisconsin valley was here crossed by two present valleys.

Glenmary Run at the park crosses a similar drift-filled valley. The second run south of Africa on the west side of Alum Creek has a rock gorge at the mouth and upstream for a hundred yards, then the rock ends against Wisconsin drift in a steep contact. A quarter mile farther upstream the shale appears in the bed of the stream for fifty feet, then disappears again and is no more found in the run. The next run northward has no rock at all. Three and one-half miles farther north in the last big run south of Cheshire and west of Alum Creek, the stream is in a rock gorge for a half mile up from its mouth, then the valley widens out, the rock disappears and

only recent drift shows in the walls the rest of the length of the run. A dozen other occurrences such as these are known in the area under discussion, and they seem to admit of no other interpretation than that they indicate buried interglacial valleys. They are pre-Wisconsin because they contain Wisconsin drift. If made prior to the deposition of the Illinoian sheet of drift, they have been cleared of all drift of the older age at the points crossed by the present streams, before the later ice sheet came—a supposition which seems quite improbable.

Plant Occupation and Soil Formation.

While the streams were carving valleys, the plants and animals forced to evacuate before the advancing ice were able to return and again occupy the territory. Probably vegetation as a whole very promptly followed the ice as the latter receded, but not with the same relative mingling of species as occurred later. The ultimate grouping and distribution at any given time is the result of conflicts and adjustments to changing conditions. As the plants took possession, their partially decayed remains from year to year added carbonaceous matter to the surface portion of the drift, thus making a soil. In depressions where water stood, water-plants grew and their remains accumulated in the pond or swamp and brought forth peaty conditions.

Whatever of soil and peat was produced during the interglacial stage would be present when the returning ice arrived in the Wisconsin stage. Most of it no doubt would be dragged or shoved along by the ice or covered up with new drift. Parts of the soil and one peat bed have been found preserved between the two sheets of drift. In the east branch of Glenmary Run, north side and about one-fourth mile up from the junction of branches, may be found a yellow stratified clay along the stream bed; above the clay is a mass of characteristic old drift covered with a weathered zone and dark soil, and above the old soil lies Wisconsin drift.

Springwater Run enters Big Darby at the southern edge of Harrisburg. A short distance up this run on the north side, the following drift section from the water up, was recorded:

		Feet.
5.	Yellow, loose, unweathered till	30 +
4.	Light gray layer, like Southern Illinois soils	1
3.	Fine, weathered sand and sandy till	3
2.	Coarse, weathered, gravel having smooth contact with No. 3 above	1
1.	Old characteristically jointed, blue drift	5–6

A mile farther up the same creek occurs 20 feet of blue drift, capped by 10 feet of a much weathered dark variety, which is overlain with several feet of fresh drift. About two and one-half miles west of Matville at the turn north of the road, in the little stream which crosses the highway, the following section was noted:

Old characteristic, indurated boulder clay for three feet above the water, then about a foot of badly weathered dark soil-like material covered with

six to eight feet of fresh gravel with unweathered drift to top of section. A steep till cut occurs about one-half mile north of Morgan station at the east bluff of Big Darby, exposing the following section:

		Feet.
4.	Weathered till and present dark soil grading down into the next (No. 3)	3–4
3.	Fresh, loose, stony yellow clay till with sharp contact between it and No. 2	12–15
2.	Much weathered, dark compact soil-like material gradually passing into the next below (No. 1).	2–4
1.	Characteristic dense, blue old drift from water up.	50

Across the Scioto from the Hartman farm the little stream which heads near Grove City is digging out old peat. At least four feet of this material is exposed, half below the water and half above. Fresh drift constitutes the bluffs on both sides here. Apparently the stream has cut into an interglacial peat bog.

All this erosion, soil formation and development of peat require time and hence give us a suggestion of the duration of the interglacial period. Evidence derived by examining valleys[1] on Illinoian drift which has not been covered by later ice sheets, points to a period from the beginning of the interglacial stage to the present some seven to nine times as long as that since the Wisconsin ice melted out. This conclusion is based on the relative maturity of valleys and completeness of the drainage system in Illinoian drift as compared with the same in Wisconsin drift, together with the amount of weathering the two sheets have undergone and several other factors.

THE SECOND ADVANCE OF THE GLACIER.

The second advance of the ice from the north was probably similar to the first. But instead of finding the topography in advanced maturity as in the first instance, the second ice sheet must have found a till plain with moraines rising above it and multitudes of youthful valleys carved in both plain and moraines. The landscape must have been something like the present except that the valleys were larger, longer and more mature; the tributaries more numerous, longer and more branched; and the interstream remnants of the till plain less extensive, narrower, more serrate at their margins, and more completely possessed by the streams. The drift of the first invasion may have been similar during the interglacial stage, in composition and structure to the present surface deposits; but the second sheet of ice rubbing over and pressing upon the older drift probably compressed, packed, and in places, jointed it,[2] and thus left it in the dense compact condition so often seen, which aids in recognizing it today. Illustrations of the power of the ice to shove and distort over-ridden material are not wanting.

[1] Chamberlin, T. C., and Salisbury, R. D., Geology, vol. 3, p. 414.

[2] Carney, F., Metamorphism of Glacial Deposits, Jour. Geol., vol. 17, 1909, pp. 473-487.

Illustrations of Ice Shove.

When the excavation for the Ohio State University Student Building was made, sand and fine gravel layers complexly crumpled were exposed below a boulder layer, recent drift, and the present soil. The boulders were much weathered, some to complete crumbling, but the drift above was fresh. The crumpled sand layers were in the older drift over-ridden by the later ice.

In a little run east of Big Walnut and leading into that stream a mile above Galena, is an outcrop of shale which is much disturbed and folded. Drift pebbles have been crowded into the shale and all much crumpled but not removed. In several places short folds and crumplings have been seen in the Ohio shale. One fine instance may be noted west of Alum Creek some three miles above Westerville; another in the clay pits opened for sewer pipe materials at North Columbus.

Possibly Several Ice Invasions.

Whether the ice entered the Columbus region more than twice is not known. That may be the case, for in other regions in similar latitude certainly more than two invasions have been recorded. If the advances number more than two, the little known ones probably antedate those better known. Whether or not there have been more than two advances of the ice is also of little significance in this region, in as much as two later known advances have both gone entirely beyond the area. Perhaps the greatest moment of the question attaches to what may have been done in the interglacial stages. It has been seen that erosion in an interval between two advances of ice gives immature valleys partly in drift and partly in rock. We must have a few youthful preglacial valleys developed as the ice came on, interglacial youthful valleys for each interglacial stage, and one set of postglacial valleys. If only an Illinoian and a Wisconsin invasion occurred, our postglacial streams would encounter two sets of buried valleys; and as the number of invasions increases, the number of sets of valleys thus encountered must also multiply. The wonder is not that we find sections of so many buried valleys, but that we do not find more[1]. As was suggested in connection with the discussion of valleys containing Illinioan drift, the fact of the preservation of so many pre-Wisconsin valleys although subsequently traversed by the Wisconsin ice sheet, is a strong argument for moderate glacial erosion beneath the last Scioto lobe. The fact that we have more or less of two sets of youthful valleys buried beneath our drift, and possibly remnants of still other systems, complicates greatly the problem of mapping any one system. One cannot always be sure to which erosion period any given buried valley may belong.

The work of the ice sheet last to deploy over this region was no doubt similar to that sketched for an earlier one; but its depositional or constructive work has been very much more perfectly preserved; primarily, because no subsequent leveler has appeared to obliterate the work, secondly because the time since the work was done has been too short for the subaerial processes of destruction to more than begin their work.

[1] At least thirty-two distinct valleys filled with drift, and now crossed by the present streams, were found. Some are very small, 50 to 100 feet across, others seem to be over a mile wide.

CHAPTER IV.

PHYSIOGRAPHIC HISTORY.

THE WORK OF THE LAST OR WISCONSIN ICE SHEET.

Reference to the map of the Scioto glacial lobe (Pl. 25) makes it clear that the last ice sheet advanced with a broadly lobate margin. During its maximum stand its eastern margin extended from near Mansfield approximately southward to Lancaster; then the margin swung southwestward past Adelphi and Chillicothe, to near Hillsboro, whence it bore northwestward to Springfield, Cable and the hills east of Bellefontaine. The lobe at this time covered from 4,000 to 4,500 square miles. Columbus and the Columbus quadrangle are pretty well centered in this great area.

Lake Deposits.

The effects of ponding back the streams, forcing them over divides, and overcharging them with waste, as outlined under the Early Continental Glacier, were apparently repeated in the advance of this last sheet. As instances of the ponding effects reference may be made to two deposits which possibly belong to the same body of water although the exposures are some fifty feet apart vertically. They occur north and northeast of Reynoldsburg.

A little over one and one-fourth miles straight north from Reynoldsburg, on the east bluff of the run leading southwest, there was found a splendid section of sands and clays, with a height of over 20 feet. The beds are horizontally stratified and consist of clays and very fine sands, but apparently without organic remains. Two sand layers carry very perfect ripple markings five inches from crest to crest and one inch high, very similar to those revealed in the Berea sandstone, and along the margins of the bed of Lake Erie today. These ripple markings of such large size seem to argue for a considerable body of static water. Just about a mile southeast of Blacklick station and where the north and south road crosses the run, appears another similar deposit of fine sand and bluish clay horizontally bedded. Plant remains badly decayed are abundant, but no ripple marks are visible.

Outwash.

As an example of aggradation during the advance of the ice, the phenomena at the private suspension bridge over Rocky Fork may be cited.

About one and one-half miles east of Gahanna the old drift in a pre-Illinoian valley mentioned on page 250, has been partly cut out, as if the stream returned to its earlier valley when the Illinoian ice melted back; then after the removal of much of the drift, stratified gravel and sand (seen in part at the top of Pl. 27A), have been laid in the strath apparently as outwash prior to the deposition of Wisconsin drift, for there is a thickness of 25 feet of the latter over the stratified material.

Compacting Old Drift.

The Wisconsin ice is probably in part responsible for the compact and jointed condition of the old drift;[1] for, with its thickness of hundreds, not to say thousands of feet and its sliding motion it must have tramped, and possibly jointed loose material over which it crept.

Carving Rock Surfaces.

It is also probably the agent which made many of the striations on rock surfaces. While the earlier ice must have made polished, striated and grooved surfaces, this last sheet, wherever it removed all old drift, would leave its markings across the older ones or first remove them and then carve its own record.

WITHDRAWAL OF LAST ICE SHEET.

Having attained its maximum dimensions and having stood there for a time sufficient to free by its melting, and deposit around its margin a well marked terminal moraine, it began its last stage, namely, its melting and the laying of the till sheet and interspersed recessional moraines, with their associated fluvio-glacial phenomena.

The location of the margin of an ice sheet is determined by the relative rate of forward movement and of melting. When ice movement is more rapid than is necessary to compensate for the loss in volume by melting, then the margin or ice front advances; but when the movement is nil, or too slow to balance the waste by melting, then the ice front retreats. The rate of melting and rate of movement are both variable, hence the ice front is oscillatory, advancing, halting, retreating and halting at various intervals, sometimes halting briefly, sometimes for a long time, sometimes retreating intermittently, sometimes advancing in a similar manner. Occasionally considerable areas of ice melt, when there is practically no compensating forward movement.

The Marcy Moraine.

With several halts occupied by moraine building, and several retreats which left a more or less featureless inter-morainal till plain the glacier ultimately withdrew from its maximum stand to the southern margin of the quadrangle. The first land within this area to be freed from its burden of ice was about two square miles in the southeastern part, that lying beyond the little Marcy moraine. Reference to the general map (Pl. 25), shows this moraine to be probably the innermost or last of the moraines grouped by Leverett[2] under the heading "western member of the eastern limb" of the Scioto lobe system. It is hummocked and kettled but usually the depressions have been drained artificially A small tile factory uses the clay, which has accumulated by surface

[1] Carney, F., Jour. Geol., vol. 17, 1909, pp. 481-484.
[2] Leverett, F., Mon. U. S. Geol. Survey, No. 41, pp. 383, 405 f.

A.—Buried talus in bluff of Rocky Fork valley near suspension bridge, one and one-half miles east of Gahanna. Bed rock horizontally stratified from center to right. Drift with boulders below, and some stratification above on the left. Ancient talus of shale alone forms a wedge between drift and bed rock, and rises from water almost to top of bed rock.

B.—Hayden Falls. About ten miles northwest of Columbus. A more resistant limestone layer at the crest of the fall. (*Photo by Dr. C. R. Stauffer.*)

wash in one of the kettles. A few are drained naturally. Outside the kettles the drift is stony. There are many rounded and angular pieces of sandstone from the hills to the north and many fragments of other stones from Ohio and Canada mixed with the clay and sand of the moraine.

This moraine lies nearly three hundred feet higher than the plain to the west and north. To make it the ice rose over the mature slopes of the resistant sandstone between Canal Winchester and Lithopolis. The presence of these rock hills so obstructed the ice that its front was here markedly held back, as may be seen by following the moraine westward and southward. It swings here quite abruptly southward as it leaves the quadrangle, because the lower land to the west allowed the ice to advance farther and more freely in that direction. The physiographic map (in pocket) shows details of the distribution of the moraine.

The Lithopolis Moraine.

After building the moraine just described, melting of the glacier came to exceed the forward movement and the ice disappeared from the hilly tract, scattering a till sheet over the mature rock slopes. Not enough waste was left here to completely conceal previous topography but sufficient to fill many valleys, and, with the little erosion accomplished, to even and round the forms of the hills and leave a good light, long-lived soil basis.

The streams in carving their present valleys have often encountered the rock, but they also reveal several very thick bodies of drift where former valleys must have existed. It seems impossible to so correlate the buried valleys as to discover any system. The map (Pl. 26) shows in dotted lines where some of these valleys are believed to be.

After the ice had melted entirely off of the hills, it seems to have pushed forward a little, shoving the drift in masses against the hillsides both east and west of Lithopolis, just as has been observed in the Alps and in Alaska. Around the village the moraine seems to be wanting. In the area east of town, there are two crests to the moraine less than a fourth mile apart but practically parallel. Each ridge is now discontinuous, and probably was always so, though erosion has done much to isolate the sections. Three deep drift-walled gorges cut through both ice-front moraines to a depth of 60 to 80 feet, but the rock is not reached in any of them.

A Marginal Lake.

Just west of these moraine ridges, the rock rises almost as high as the moraine, and the drift is so thin that the little stream has cut down through it to rock. At right angles to the east end of the moraines lies Chestnut Ridge of solid sandstone rising one hundred to one hundred

and fifty feet above the morainic ridges. From the south end of this ridge, high rock topography connects across westward with the hills upon which Lithopolis stands. Thus, before the ice came there was a broad valley opening north, and bounded on three sides by rock hills. When the ice deposited drift in the north side opening, local water was ponded and a small lake, marginal to the ice, was formed. Clays and sands were laid on its floor but no streams other than hillside rills and surface wash seem to have fed it, hence no deltas remain and the shoreline phenomena are very weak. They consist simply of a sandy zone about the same height, only preserved in places. The topography and the clays, now badly dissected, are the best evidence of the existence of this little marginal lake. That it was short-lived is shown by the absence of outlet as well as by shoreline feebleness. That the moraines are due in part to pushing is believed, both because of the shortness of the lake history, and because of the failure of the moraine, beyond where it could be pushed up against the rock hills. The difficulty, however, of identifying pushed moraine is recognized. Beginning a mile west of town the moraine leads away southwestward, flanking the hills nearly four miles, first as a weak terrace, then as a ridge, until it smooths out into the level till plain and entirely disappears without reaching the edge of the quadrangle.

Phenomena due to Melting of Stagnant Ice.

After the time occupied in building the moraine which helped retain the lake, a short period if much of the deposit was pushed up, the ice-sheet seems to have passed through a period of dissipation with essentially no movement forward. This melting would probably permit the waters of the lake to escape. The areas of rather characteristic morainic topography around Waterloo, possessing kettles and sags and swells, together with those across Little Walnut to the south and those south of Groveport for two or three miles, seem to defy systematization. They may be classed as ablation moraines,[1] left by the melting of stationary or stagnant ice, and consisting largely of drift distributed unevenly in and on the ice, freed and let down to the ground as the ice vanished. Another area probably of the same origin, but possibly to be correlated with the moraine mentioned on either side of Lithopolis, occurs farther northward just east of Oakland.

Starting about a mile southwest of Winchester a circuitous, crooked ridge or row of hills of sand and gravel leads irregularly westward a mile where it is crossed by Little Walnut. From there it can be traced southward, then southeastward, bifurcating at the end and terminating,

[1] Tarr, R. S., Folio U. S. Geol. Survey, No. 169, p. 124 (Field Edition), describes this phenomenon, which must have been common in many places as the ice-sheet was disappearing. Also, Zeitsch. fur Gletscherkunde, III Band, 1908, pp. 85f.

after over three miles of crooks, less than a mile and a half from the starting point. The whole feature is known locally as the Irish hills. It consists of good clean gravel and sand stratified obliquely down slopes, and crossbedded, but it is always covered with one to ten feet of unstratified drift. Where it is intersected by the stream the 30 to 35 feet of gravel rests on blue, hard till exposed ten feet above the water. Its structure indicates that it was made by running water over-charged with waste and flowing in confines now removed. The waste on top further testifies to an origin underneath ice, which, as it melted mantled the gravel with till. Furthermore, it must have been formed when the ice had ceased to move forward, else the restraining walls of ice would have brushed it and confused its stratification; and when the ice had become thin, else the weight of the ice would have closed any open spaces or tunnels through it. From the position of pebbles in the ridge, and the position of the ridge with reference to the moraine, it is believed that the water flowed toward the divided end. Such a deposit is classed as an esker. Other minor gravel ridges of this same sort occur two and three miles respectively east of Brice and south of the elbow in Blacklick Creek.

The head end of the Pickerington[1] esker now bearing the Pickerington school building, also belongs to this same class of features and dates from the same time. The esker drainage must have been eastward, while the present drainage is westward. About a mile west of Duvall are some sand ridges, esker-like but not conspicuous, which are the beginnings of the large esker extending from this point southward nearly to Circleville.[2]

In this vicinity the Scioto Valley gives off a branch on the eastern side which continues some miles southward and then rejoins the main valley. The river must have been a divided stream here immediately subsequent to the melting out of the ice. The floor of the side valley, now entirely abandoned, lies about twenty feet below the till plain, and about thirty feet above the present river. It must then have been abandoned for a long time, probably more than half of postglacial time. A minor stream enters it from the till plain to the east and flows northward to the river. The Ohio Canal from Lockbourne southward occupies a part of the abandoned channel.

West of the Scioto in this latitude is an old channel now occupied by a minor stream entirely too small to have made it. This, too, is a remnant of early post-glacial drainage before the adjustments were as perfect as today. At the same time the precursor of the Big Darby was a divided stream, and one part has left an abandoned channel some three miles long lying west of the Darby and south of Harrisburg. The history of this channel has been carefully studied and its origin explained.[3]

Two and one-half to three miles due north of Canal Winchester, is a group of gravelly hills of rather weak relief resting partly on the sandstone and partly on drift. In places the gravel is well assorted but in other parts

[1] Leverett, F., Mon. U. S. Geol. Survey, No. 41, pp. 428-429.
[2] Idem, pp. 429-431.
[3] Nichols, R. H., Ohio Naturalist, vol. 11 (1910-11), pp. 210-213.

it is not. Two large kettles in the group contain water, and in the northern part of the area was once a lake of two or three hundred acres. It is now drained and furnishes fine rich soil, as such places usually do. About a mile north of Winchester is another minor lake bed as is shown by its black, humic soil and sandy margin.

A small hill two miles west of Lithopolis, which may easily be mistaken for a morainal form, is an outlier of Bedford shale on the Ohio shale.

Shadeville-New Albany Moraine.

Another minor halt of the ice-front is marked by a series of patches of moraine topography, not a continuous band, entering the quadrangle from the northeast at a point about three miles east of Center Village, developing into a fine strip of moraine southeast of the village, and extending as such southward and southwestward past New Albany and Ovid. Here it becomes more patchy but can be traced southward past Taylors to Brice,[1] then southwestward to a well-defined ridge somewhat uneven-topped and containing two or three excellent kettles about two miles northwest of Groveport. This ridge portion is crossed both by the Hocking Valley railroad near Big Walnut Creek and by the Groveport pike and Scioto Valley Traction line. From the latter the kettles may be discerned as cattail swamps or ponds north of the road. The other branch of the Scioto Valley electric crosses the moraine a mile north of Lockbourne. While the contour lines with the 20-foot interval do not lie so as to show any particular difference in the altitude on opposite sides of this part of the moraine, the four locks in the canal offer positive testimony to the difference, which can also be seen by the student at proper points. Farther northeast along this moraine a reverse difference in altitude on opposite sides appears, because the deposit was laid on a rising rock slope. The ice lay on initially lower ground than that upon which the moraine was placed, and that outside the moraine was still higher. On account of this relation the moraine appears in some places as a terrace on the hillside, with lower land on the ice side than on the other.

Southwest of Lockbourne and across the Scioto are a group of swells with several kettles, some still swampy; and westward from them around Commercial Point, may be found a considerable number of little knolls. At Matville and vicinity are others, and westward from Harrisburg as far as the Franklin-Madison county line are many more. From Lockbourne on, one would hardly be justified in calling the isolated hummocks and knolls moraine, if it were not for the well developed moraines farther east and northeast with which these features seem to connect. The crookedness of Springwater Creek, the lack of symmetry in its valley and the abundance of springs along its course are suggestive of moraine modified by the stream, which probably owes its position largely to these morainic accumulations.

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[1] Leverett, F., Mon. U. S. Geol. Survey, No. 41, p. 427. This is the moraine, a part of which Leverett describes as occurring seven miles east of Columbus.

Associated Phenomena.—Associated with this moraine are several features of importance which date from the same time as that of the moraine. First, the moraine terrace, explained in the previous paragraph, occurs in the southeastern corner of Delaware County and again a mile east of New Albany, where it holds Blacklick Creek to a southward course, although the initial postglacial slope descends faster westward. From two and one-half to three miles straight east of Gahanna in this morainic belt are two north and south drainage lines not now occupied by streams. The eastern one about a half mile long is at the foot of a steep, west-facing slope and probably represents the work of marginal drainage, water flowing along the ice-front and restrained on one side by ice, on the other by the rock. When the ice was gone it left a one-sided channel. The western channel is a little lower, was used after the completion of the former when the ice had melted back a little, and was probably only in use a short time. Gravels deposited south of these channels were in part dragged through them.

At Lockbourne the moraine is fringed on the south side by an inconspicuous outwash plain, or better, by a frontal apron, because it is not confined in a valley but spread thinly. It consists of gravel and sand, coarser near the moraine, and extends two or three miles southward. This deposit has recently been extensively cut into for grading materials by the Norfolk and Western Railway company, thus revealing its nature.

The halt for the construction of this moraine must have been a short one, and much shorter in the southern than in the eastern parts. Not only does the size of the moraine sustain this point but the relative distance between the moraines in the southern and the eastern parts supports the same conclusion. The withdrawal of the ice between the making of the Lithopolis moraine and that of the Shadeville-New Albany moraine was much more extensive around the southern border than along the eastern edge; hence, the duration of the halt may consistently have been less here at the south, resulting in the smaller moraine. The crookedness of the moraine suggests that the ice margin was quite ragged during its building. The unequal development of the moraine may be the result of varied distribution of drift in the ice, which might well result in differential melting and thus account for the ragged margin of the ice.

Features Between the Shadeville-New Albany and the Lithopolis Moraines.

While the ice-front was withdrawing from the earlier to the later of these moraines, the history chronicled in the former similar period of ice melting was repeated with variations.

The Hibernia Esker.—This ridge distinct for more than a mile each side of the National pike and Ohio Electric railway at Hibernia, eight and one-fourth miles east of High street in Columbus, is a rather prominent feature. Where the highway crosses the ridge, about a mile south of Hibernia, it is thirty feet high above the till plain,[1] and the well here did not reach rock at a depth of 70 feet. To the south the ridge divides and terminates without a sand plain. Northward, it decreases in height and flattens out. The stream crossing it, evidently found it low and now has cut it entirely away at the crossing. A large gravel and sand pit is opened in the esker at Hibernia. Beyond this point northward the ridge is strong for a half mile, then less marked for nearly a mile. The road follows it closely. Here it entirely disappears except for a short section of low ridge a mile west of Taylors and south of the Pennsylvania-Baltimore & Ohio railroad. It is made consistently of gravel throughout and capped with a mantle of till.[2]

Gahanna Esker.—Northward about two miles farther is found the southern member of a group of related features consisting of kames, esker and sand-plain which beautifully illustrates their interrelations. Each feature is small and somewhat mutilated by erosion but readily identified. The sand-plain or esker-delta is at the southern end. At the other end west of Big Walnut at Pinhook is the kame area. From the latter southward mostly on the east side of the stream are scattered the fragments of the esker, opened in several places for gravel. The ridge fails about a mile north of Gahanna and the sand and gravel-plain begins. Broken by erosion at Gahanna, the sand-plain continues south and west of town for a mile and a half on the opposite side of the stream. This complete group of kame, esker and sand-plain seems to be in no way connected with the Hibernia esker, but was formed later as the stagnant ice melted.

Galloway Esker.—Beginning more than a mile from Galloway up Hellbranch Run, small ridges of gravel occur. The series continues intermittently down stream for nearly four miles. The stream and roadmakers have removed considerable portions, but enough remains to mark the series as an esker, made during this same period of ice recession. South of Galloway occur three or four lake beds aggregating over 100 acres of rich black soil. They occupy as many large shallow kettles in the drift. Stream work, aided by artificial means, has completely drained them all.

Abandoned Channels.—Two and one-half miles east of Pinhook, an abandoned channel twenty feet deep leaves Rocky Fork valley on

[1] Leverett, F., Mon. U. S. Geol. Survey, No. 41, pp. 430-431.

[2] Several recent openings in this ridge reveal its true water-laid nature. The boulders occurring upon it are undoubtedly a part of the unstratified drift cap.

PLATE XXVIII.

Kames of Spangler Hill, four miles south of Columbus. Looking south.

the west side and continues southward parallel to the latter for about one and one-half miles, then again joins Rocky Fork. Probably the precursor of the present stream was, during the melting of the ice, a divided stream and here as elsewhere, the ice-drainage waters were eroding instead of depositing.

Kames, Baker Hill.—Two miles or more south of the Driving Park, Columbus, and near the Scioto Valley Traction line is a peculiarly stratified, rounded, gravel and sand hill rising fully 50 feet above the level till plain. It may probably best be called a kame, although a considerable portion of the stratification is entirely too steep, contorted, and tumbled for purely deposition work. No kettles are found on its surface, but rather the whole form is smooth and rounded remarkably like a low drumlin. The mass must have been laid with some ice underneath and then let down by melting to give such a tumbled structure as is constantly presented in the cuts made by removing sand and gravel. A thin sheet of unstratified drift mantles the lower slopes, but there seems to be none at all over the top, indicating that no waste-burdened ice existed over the place when deposition ceased. This hill has proved of so much economic importance, because of its contents, that the Norfolk & Western Railroad company has constructed a stub track to the hill preparatory to its complete removal.

Kames, Spangler Hill.—Four to five miles south of South Columbus are the finest kames to be found in the area. They are situated two to three miles north of where the margin of the ice stood when the Shadeville-New Albany moraine was built and cover a little less than one square mile. (Pl. 28 and Pl. 29 A.) They consist of some twenty or more gravel hills ranging in height from a few feet up to sixty or seventy, above the surrounding till plain. Obliquely stratified sand and gravel are exposed in several places where openings have been made. Huge kettles, empty with one exception, are enclosed between the knobs. In the eastern part is a kettle lake-bed now thoroughly drained, floored with fine black soil and under onion culture. (Pl. 29 B.) The former shorelines, with a small sand bar on the southwest side of the area, can be traced much of the distance around, and they, with the lake-bed deposits and the smoothness and levelness of the lake plain testify to the presence and extent of the now extinct lake. The deposits are not thick and probably came largely from the moraines on the east. The lake covered at least twenty acres at its maximum, and must have been filled nearly full of clay and organic matter for the shoreline features rise but very little above the lake bottom. Around the kame area and connecting with the Scioto Valley at the north end and with the Big Walnut at the south, extends a broad, shallow, abandoned channel through which water flowed at some time during the melting of the ice.

A considerable supply of drainage would be required to build so large a group of kames as this. The arrangement of hills, lake-bed, channel and moraine indicates that at the cessation of forward movement and the completion of the moraine above mentioned there was here a notch or re-entrant angle two miles deep in the margin of the ice. Into this notch drift, making moraine, was piled, and now gravel, a little farther north, making kames. As shown on the physiographic map, some of the gravel accumulated in the kame hills while other parts were carried southward and laid along the Scioto as outwash. Much of the latter has been eroded.

Moraine for a mile south of the kames should be correlated with that described under the heading Shadeville-New Albany moraine.

Tumuli—In Harlem Township, on the New Albany strip, and around the village of New Albany, are a number of low rounded to ovoid drift hills or tumuli. They range in height from ten to twenty-five feet, in length from an eighth to one-half mile, and in width from an eighth or even less to rather more than a fourth mile. Stony till is almost the universal content of each, but a few were found containing some stratified gravel and sand. One mound two and one-half miles east of Westerville and one-third mile south of the county line near the highway, contains no gravel and very little drift, but seems to be of shale. This is the only one known to contain bed rock. Many are known to contain no rock. They seem to be essentially drift features and similar if not identical with other knolls in the moraine last mentioned.[1]

Outwash.—Gravel along the Scioto Valley, recent and fresh, but covered sometimes with a few feet of till is abundant. The map shows only the surface exposures and much of this may be of later date. For a mile or more east of that shown on the map between South Columbus and Shadeville, the gravel occurs and is reached below the till by many wells. At the starch factory in South Columbus flowing wells have been made ending in this gravel at depths of fifty feet and more. A half mile farther east, a large gravel pit has been opened in it. Wells between here and Baker Hill reveal the gravel only at depths of fifty feet or thereabouts. The thick till cover both here and southward along the river shows the gravel to have been laid under the ice and covered a little in the final melting, or to belong either to the advancing ice or to an earlier invasion. In some places it seems to have been but very little covered. Near the river, part of the cover may have been removed. The later deposits are discussed on page 287.

The Till Plain.—Southwestward from Columbus the topography is exceedingly level and is locally known as "the plains." The apparent uniformity is largely in form, for even the surface material varies considerably. In the spring when the ground has been prepared for planting and before the crop has grown to cover it, the land is seen to be spotted,

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[1] Many of these features were mentioned by Leverett, Mon. U. S. Geol. Survey, No. 41, pp. 426-27. Better opportunities for study have been given the present writer, and correlations can now be made which were not possible when the former work was done.

A.—Kames of Spangler Hill looking southwest. The kames stretch away about a mile. On the left, over the fence, is the lake bed.

B.—Looking east of Spangler Hill. Moraine east of lake bed in the distance. Looking southeast.

dark to black blotches in a gray or yellowish background. The darker areas are usually very slightly lower, and can sometimes be located even when the crop is grown, by the size and vigor of the latter or by its darker green color. The darkness of color in the soils of these patches is due to organic matter. It seems probable that when first made, the till plain may have been a little less level than now, and that the depressed areas, once more or less swampy, have been aggraded by surface wash of clays and by the admixture of partially decayed vegetable remains. Thus, there has been made from a very slightly undulating till plain a still more level feature. It has been thought that much of this level country was once occupied by a glacial lake,[1] but there is no stratification to be found in the surface materials, except in a few of the larger and presumably once deeper black earth depressions. The part played by surface wash in augmenting the levelness is undoubtedly small.

South of Columbus and east of the Scioto, the plain is often equally level though in smaller tracts, because the streams have cut little valleys across it. This region has long been known as the "barns," a corruption probably of the "barrens"[2] in deference to its former relative unproductiveness as compared with surrounding tracts.

The Westerville Moraine.

After this period of excessive melting with the forward movement at a minimum or nil, a slight change in conditions began and the balance of melting and advance was again established. The margin of the ice during this minor halt is marked by the Westerville moraine which enters the area somewhat scattered in the northeast corner, leads westward four to five miles, then southwestward as a series of isolated hummocks to a point two and one-half miles south of Galena and west of of Big Walnut Creek.

Here unmistakable moraine begins in a hundred-acre patch of hills somewhat modified by erosion and cut entirely in two by a little run. Nearly southward from this area the moraine continues as a narrow, rolling belt to the Delaware-Franklin County line, then widens into a broader, bunchy, kettled strip nearly to Blendon. It probably never was well marked as moraine beyond this place, either because locally, the retreat was too rapid, or because the ice was too free from debris. Several phenomena however, indicate the position of the ice border southward to a kettled rolling area a mile southeast of Linden, and then southwestward to gently rolling moraine topography between Alton and Galloway.

Further evidence upon which the ice-front may be traced follows. Very thick drift at Minerva Park and southward to Linden with con-

[1] Orton, Edward, Geol. Survey Ohio, vol. 3, p. 646.
[2] Bownocker, J. A., a fact and explanation contributed orally.

siderable work of minor streams in it, sufficient to destroy true moraine forms, marks the course. Beginning at Park's Mills east of the creek and leading almost a mile and a half north is a marginal drainage channel with the rock east of it and gravel and drift to the west; and five hundred yards east of the northern or upper end of this channel is another short one behind a small hill, cut in shale but not used today at all. These abandoned channels were carved by marginal waters during the minor halt of the ice, while the ice-front was crowded a little against a rising shale slope. Fair moraine topography with two or three swampy kettles toward the south occurs one to two miles southeast of Linden. These swampy tracts have been scraped out and walled in a little to make a series of artificial ponds for duck raising and ice cutting. Through the city nothing remains to mark the ice border, but west of Greenlawn cemetery is a group of morainic hummocks and north of them several more. Along Scioto Big Run from the point where it is crossed by the Baltimore & Ohio Southwestern railroad, between Briggsdale and Urbancrest, to the Big Four crossing of the same stream three miles farther up, the topography is very irregular. Hummocks of drift are common in positions where the stream could not have made them, and sections of the valley mark places where kettles once were, having now been cut through by the stream. This creek nowhere touches rock but has cut deeply into drift. It seems probable that if no stream had modified the topography where the creek flows, one would with assurance and propriety map moraine, Westward from the Big Four crossing above mentioned, numerous low hummocks and minor swells with occasional kettles, now drained, mark the margin of the ice during this halt and permit it to be traced to the Big Darby. Off the quadrangle westward one-half to one mile along the National Pike and south from it, thickened drift, gravelly hummocks and black-soiled sags mark the same line. The curve traced by this series of features is quite similar to that of the Powell moraine yet to be discussed.

The Till Plain and Associated Features.—Northward from the western half of this moraine for a dozen miles, including the Hilliards, Powell and Worthington interstream areas, practically as far as the Delaware-Franklin County line, the till plain is remarkably level and featureless save for the post-glacial erosion to be described subsequently. The Toledo & Ohio Central railroad passing over this plain, through Amlin and Kileville covers 25 miles without a turn, a grade or a cut except where it crosses a couple of little runs and the Powell moraine.

Just south of the road a mile north of Marble Cliff is found a little group of kettles in the till plain. One of these has become a peat-bog, and if one may judge from the black, humic condition of the soils, others certainly were somewhat peaty when drained. In fact, many areas on the Hilliards and Powell strips south of the Powell moraine must have been swampy if not even slightly peaty at a prehistoric date. The plain is as spotted with

dark and light soils as is that farther south. Corroborative evidence is recorded on the Soil map.[1]

Drainage lines established and used during the melting of the ice in its stagnant condition following the making of the Westerville moraine, are now marked by several interesting features. The Columbus esker fully described by Morse[2] is a little ridge (Fig. 14) with its accompanying sand plain to the south lying about half a mile east of the Ohio State University campus. It has been nearly obliterated by street and building excavations and grading.

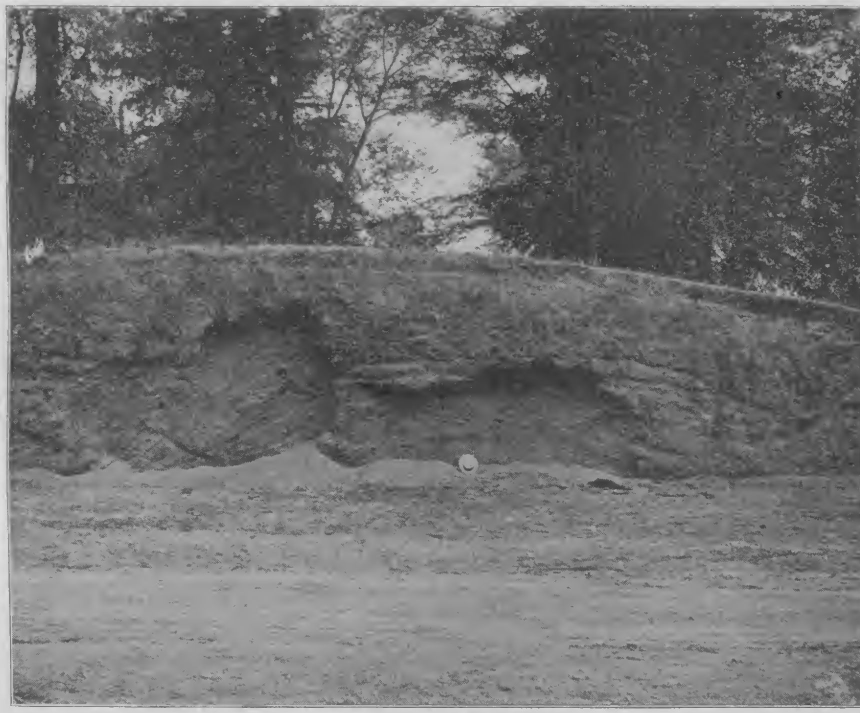


Fig. 14—Columbus esker. Structure revealed at 16th Avenue between Summit Street and Indianola Avenue. Looking south.

So far it has been impossible to trace any connections farther than mapped. If the southern part of this feature marks the edge of the ice during the Westerville moraine building (which seems improbable), the ice margin must have been very crooked here. It is more likely that the esker and sand-plain were made wholly under the ice, as both are covered with a sheet of till. Another drainage line lies west of the Olentangy and begins about opposite Clintonville. This is not an esker, but a channel, now separated from the Olentangy by a sandy or gravelly area sometimes in the form of a ridge. It may be traced from the starting point mentioned, southward a mile and a half to where it divides for half a mile, the parts reuniting near Lane Avenue; from whence the course can be traced to a point opposite the State University. Here it leads into the present Olentangy channel. A third drainage line is a channel, mostly in rock, west of the Scioto, over a mile in length, and extending from a point opposite the Columbus Fishing and Gun Club southward. These last two channels have no streams at present. They are interpreted

[1] Map 20, Columbus sheet. Bureau of Soils, Rept. of Field Operations, 1902; and Map 30, Westerville sheet, Bureau of Soils, Rept. Field Operations, 1905.

[2] Morse, W. C., Ohio Nat., vol. 7, Feb., 1907, pp. 63-72.

as water ways during the waning of the ice, but probably not long after, because the present river courses must have been better water ways, and hence would take care of post-glacial drainage. They certainly have been abandoned during the cutting of the present valleys below their levels.

Two and one-half miles northeast of Westerville a channel cuts obliquely across the moraine. Its length is about one-half mile, width a hundred feet, and depth ten or twelve feet. Its walls are quite distinct, although it has not been used for ages. It was undoubtedly made and used by water from the melting ice for a short time during its recession, but ever since has been isolated and wholly unconnected with any drainage system.

The Powell Moraine[1]

One cannot with certainty discover how far the ice melted back during the period of recession just discussed, but beyond a question the minimum retreat was to the present Powell moraine. The rather bold south-facing front, the very considerable height of the moraine together with its uniformity in height, its lack of kettles, and the total absence of any ice front phenomena on its inner border indicate that the moraine is submarginal, i. e. that the nose of the ice lay upon the moraine during the accumulation of the latter. While the western half of the moraine in this area sustains the argument very well, the eastern part was probably less over-ridden. Since the moraine is rarely less than a mile in width, and often two miles wide, it seems probable also that the ice-front oscillated during the building, moving forward more rapidly than it melted, then melting back a short distance, only to advance again over the moraine. The compactness of the drift about Powell, New California and other points as reported by well drillers and as seen in stream bluff exposures, further corroborates the theory of a submarginal moraine tramped down by over-riding ice.

In several places, the south-facing moraine-front is very conspicuous. Perhaps as marked a place as any is about two miles south of Powell. For several miles to the south of the edge of the moraine, the level till plain stands at practically nine hundred feet above sea level. One approaching the moraine-front on this plain sees a gentle slope extending east and west and rising northward thirty to forty feet in one-fourth to one-half mile; while to one standing on the moraine and looking southward, the till plain seems to stretch away for a long distance, but on a distinctly lower level. Thirty feet in one-fourth to one-third of a mile gives a slope a trifle steeper than one degree. This is extremely low, but conspicuous among slopes like those of the till plain—two or three feet in a mile. The change of slope is quite marked. The Hocking Valley railroad rises on a long grade of a mile before the moraine is reached, then it enters a cut of twenty feet or more and so rises to the moraine top at Powell. Nearly every freight train from Columbus has two engines to a point beyond Powell. Not alone because of the moraine is the extra power needed, but because the Hocking Valley station in Columbus is on the Scioto flood plain about 720 feet high, and the engine must climb in fifteen

[1] Leverett, F., Mon. U. S. Geol. Survey, No. 41, pp. 525-531.

miles out of the valley, to an elevation of 920 feet at Powell. The average railroad grade is 13 to 14 feet in a mile, while the slope of the moraine is probably as steep as 100 to 120 feet in a mile.

West of the Scioto, the moraine rises 50 to 70 feet in about a mile, or from a 950-foot till plain to moraine summits of 1,000 to 1,021 feet. A rather marked moraine-front can be seen a mile north of Flint on the Big Four and Pennsylvania railroads. These begin to grade half a mile south of the moraine, and make half the altitude necessary before reaching the moraine, then they make a cut until they emerge on the plain north of the ice deposit. For three miles southwest of Galena, along the Cleveland, Akron & Columbus railroad, the southeast-facing moraine-front shows distinctly. The railroad company has cut off the nose of the moraine about a mile south from Galena.

One would be entirely excusable for not recognizing this moraine until across it, if he approached it from the ice side; for it grades imperceptibly into the till plain here and rarely has a kettle on its summit. Levelness or broad shallow sags and low swells characterize the whole surface except along the larger streams where modified by erosion.

The moraine is probably widest at Powell or just east of Alum Creek, and averages over two miles in width entirely across the Hilliards strip. Across the Worthington strip, it averages about one mile in width. It is narrowest east of Africa for two miles, where all unevenness of surface is confined to a strip one-half mile wide, but across the rest of the Westerville strip and on northeastward beyond Galena and Sunbury to the margin of the quadrangle, the width of a mile to a mile and a half is constantly maintained. The moraine was once continuous across the area except for two or three small stream cuts where the Scioto and Olentangy rivers and Alum Creek now cross it.

Phenomena Accompanying the Moraine.

Among the features whose origin is wrapped up in the history of the Powell moraine are a lake (now drained), an outwash plain, and two or three drainage channels. About half way between Galena and Sunbury and nearly parallel with Big Walnut, between the wagon road and the Cleveland, Akron & Columbus railroad may be seen a channel a mile in length and in its middle and southern parts quite distinct. (Pl. 30 A.) It evidently carried water near the ice margin, for a short time, after deposition of drift had begun. Its preservation means that at this point the ice did not again advance over its first deposits. Between Westerville and Africa in a complicated mass of moraine, somewhat modified by stream erosion both during the melting of the ice and post-glacially, two channels now wholly abandoned by water are easily traced. The longer one begins about a half mile south and a half mile east of Africa and continues southward a mile and a half, then turns southeast for a half mile. The shorter one begins one-fourth mile east of the south end of the other and continues in the same direction, southeast, for a half mile or more. These two were probably continuous when made, but their connection could not be established.

Together they reach almost entirely across the moraine and must have been in rather constant use during its building. When the ice was gone, the waters seem to have crossed the moraine in what is now Alum Creek Valley.

East of Flint an area of four or five square miles, partly in each county and extending entirely to the big Powell moraine, has, according to the topographic map, intermittent streams. The land is very level, and surface drainage seems to be poor, but the land is not wet. It is too sandy. Water, which would normally flow away in surface streams, sinks. The soil survey map[1] shows the soil to be streaked, strips of clay loam alternating with black clay loam. Below the black soil the subsoil is silty. This is all in accord with the conditions, but it should be added that there is considerable fine sand in the subsoil. The area is essentially an outwash deposit of fine material spread as a thin sheet at this point in front of the Powell moraine.

Most of the drainage of the Powell moraine, so far as this quadrangle is concerned, went in the present valleys, for at no other point across the whole moraine-front was any outwash found, save the minor deposits along the present drainage lines. The drainage seems not to have laid down much waste during the making of this moraine, for only very limited deposits occur down the valleys from it. Along the Darbys very little occurs which could be called outwash Recent stream gravels and sand are found at several places, and possibly some of the areas mapped as outwash belong in this class.

Around Columbus are a dozen square miles of gravel-covered territory. (See map in pocket). Some of this is mapped as flood plain, because at present subject to floods. Beneath the alluvium, however, the gravel is found in almost every cut. The State House well[2] shows the gravel to extend downward at least sixty feet below the present stream. Its surface, even in undisturbed areas, is lower than the till plain, and over large tracts a portion of the deposit has been carried away. With such a depth, the deposit can hardly be all post-glacial. The lower part may have been laid during a previous ice invasion or even during the oncoming of the Wisconsin sheet. While the ice was melting back from the Westerville moraine and before the building of the Powell moraine, erosion took place; then during the building of this latter moraine, the waste-laden waters deposited in the valley large quantities of sand and gravel; so much, in fact, that the valley was filled nearly level full. Thus it happens that the outwash plain is not quite as high as the surrounding till plain. It is not believed that the valley filled was much deeper than the present valley, possibly not as deep here where the deposits occur, and certainly not nearly as deep up stream toward the moraine as the present ones. The steep grade from the moraine to this point prevented the deposition, while the greater depth here and consequently lower grade for some distance below encouraged deposition.

On the western side of the quadrangle a mile or so south of New California, the moraine seems to have enclosed a basin. It has distinct moraine nearly around it, silts across its floor, and sand around much of its margin as a small beach. Sugar Run enters it from the northwest, sluggishly traverses the whole length and emerges at the south. Since the clays and silts and the beach deposits establish the fact of a former temporary lake, there must have been a barrier across the south side as

[1] Westerville sheet. Field Operations, Bureau of Soils, 1905.
[2] Newberry, J. S., Geol. Survey Ohio, vol. 1, pp. 113-114.

A.—East wall of an abandoned valley between Galena and Sunbury, west of road. The lower clump of trees is in the channel. The west wall of the valley does not appear in the figure.

B.—Alluvial terrace at Harrisburg. Looking southeast from the road in north edge of town. Terrace is nearly half concealed by the tall corn on the flood plain.

on the other borders. This has been removed and the basin drained after having been nearly filled with sediments and organic matter. There is no delta to be seen at the upper end; on the contrary, the lake plain and flood plain of the stream above, seem to be perfectly graded to the same level. It is believed that the basin is due to uneven deposition of drift, and probably not to an ice block, as the margins nowhere exhibit evidence of having been built against something now gone.

Subsequent Glacial History.

When time enough had elapsed for the building of the big Powell moraine in the ways suggested above, the balance of process was turned—melting exceeded flow—and the margin of the great glacier again began to recede. In this recessional move no stream deposits of any kind seem to have been made within the area. The till plain is continued as between the other recessional moraines and with about the same levelness. No more halts even of the shortest duration are recorded within this quadrangle, but in the territory to the north may be found the records of repeated halts and recessions, until the ice had melted back beyond the divide and the marginal Lake Maumee became possible.

In the conclusion of this chapter on glaciers and their work in the Columbus quadrangle, let it be noted that the events and the succession of events here recorded are a part of a great whole, namely, the story of the Glacial period in America. The facts presented might be duplicated in a dozen quadrangles of the same size along similar zones of the drift-covered portion of North America. No tract would have its record written with exactly the same characters, nor would it tell exactly the same story; yet there would be remarkable similarity. The problem of deciphering the inscriptions, once learned, would be easy in other places and the methods would apply in hundreds of instances.

CHAPTER V.

PHYSIOGRAPHIC HISTORY.

POST-GLACIAL.

Post-glacial history began considerably earlier in the southern part of the area than in the northern, but the total post-glacial time has been so long that any advantage thus gained is scarcely discernible today.

Beginnings of Valleys.

As the ice left the lands, none of the valleys now so attractive and important were present except those used for glacial discharge, mainly north and south valleys; and these must have been very youthful. The lands at first were bare and free from vegetation; but undoubtedly then as now, in front of waning glaciers, the vegetation crowded close up to the ice and possessed all but the newest surface each year. The first plants to grow were not the present flora, but a more northern one which had been crowded south by the oncoming ice, and which was now following its cold usurper back to its early home. As the soil became better and climatic conditions more salubrious with the lapse of time and withdrawal of the ice, the present flora crept in and became adjusted element to element, while most of the more northern plants migrated farther or perished. A few, however, remained to surprise and delight the zealous botanist and testify, with the drift, to the former presence of the ice.

Such streams as the Darby, Scioto and Little Walnut in the southern part, probably extended from the very ice front or even beneath the ice a short distance at times, southward as at present. These streams increased in length as the ice receded, but probably not much in size except as they took on new tributaries because their waters were largely of glacial origin.

The Courses of Major Streams.

Several items have been given which bear on the origin of the major streams. The Scioto and Olentangy seem never to have been marginal in this area, while Blacklick from its sources in the southeastern corner of Delaware County, practically through its entire course was from the start, and even yet is, a rather close follower of the moraine. At a little later stage, Rocky Fork was approximately marginal through many miles of its upper course, although the ice did not halt long enough to leave moraine where the stream now flows. Big Walnut below Gahanna flowed away from the ice front; from Pinhook six miles south-

ward it was a subglacial stream close beside its present channel, while it made the Gahanna esker; from the same point northward six to eight miles it grew as the ice melted out, and later, for the upper three miles or from Galena northward it was marginal. When marginal, its channel must have been similar to abandoned marginal channels noted in the same vicinity except that it was occupied by a stream; and, if streams had persisted in the now abandoned channels, they must have become by today indistinguishable from ordinary present day valleys.

Alum Creek from the turn at Blendon southward three or four miles was in a marginal channel. As the ice melted, the stream dropped to the lower present course and the upper channel was left behind. Farther south it swung across the new till plain in a consequent course to Big Walnut Creek and the Scioto. From Blendon northward to the limits of the area, the stream must have taken its start at the ice margin and flowed directly away, growing as the ice vanished. Its channel through the moraine was once divided; and probably both parts resembled at first the abandoned channels above Westerville, except that they had more youthful slopes than those. Years of weathering and surface wash have widened the channels and matured their slopes.

.Scioto Big Run was given its direction by the ice margin and moraine deposition, and it received marginal drainage during the making of the Westerville moraine.

These may all be classed as consequent streams, taking their initial courses across the drift in accordance with, and in consequence of, initial slopes. A few slight, subsequent adjustments here and there have been made.

The relation of these streams to outwash deposits has been watched for carefully. It might reasonably be expected that outwash would be found along each valley down-stream from each moraine. Such, however, seems not to be the case. Outwash accumulates in ready-made valleys or on the plains beyond the moraine, if the slopes, volume of water, and supply of waste are so adjusted as to make it necessary. The scarcity of gravel and sand deposits suggests that the abundance of water was able to carry most of the waste beyond the limits of the area, even with the moderate grades provided for the streams. Boulders along the Scioto and Olentangy below the Powell moraine witness to the fact that the streams carried away all in their courses but the boulders, sorting them out because of their size to be left behind. On the outwash in and below Columbus, the Scioto must have been left, when aggradation ceased, with a braided or divided channel. Evidence of this condition is found in the abandoned channels south of Grandview, and among the gardens south and southeast of the cemeteries. Other cases of braided channels have been treated in connection with the subject of abandoned channels.

Beginnings of Laterals.

As the streams proceeded to deepen their valleys, each of those with divided course soon got all its water together, taking the channel which in this stage deepened the fastest, and abandoning all others. As these main valleys were deepened, drainage down their sides washed waste in and thus widened them. Then the surface wash became concentrated in places along certain lines and by erosion developed small lateral valleys. These constitute the fringe of subsequent later valleys, so marked a feature along the main valleys in the northern half of the area. (See topographic map in pocket.) There are many of them in the southern half, but they are smaller and shorter and do not show so well on the map. Where the Scioto and Olentangy rivers, and Alum Creek cross the Powell moraine their laterals have so far destroyed the morainic topography that moraine should not be mapped, although till yet mantles the rock in these places. In these gaps in the moraine, probably made by the carrying away of drift, the map shows till sheet.

Many of the smaller streams are intermittent, i. e., they do not flow all the time as do perennial streams. This is due to variations in the supply of water—irregularities in rainfall. The absence of springs is especially conducive to intermittency of streams, because such absence leaves them with no supply when dry seasons come. The floors of the channels of these smaller streams frequently consist of a bed of gravel and stones into which the water sinks and creeps along out of sight. Others are floored with jointed and partly dissolved limestone, having secret passages below, which conduct part of the water away. Since these two types of floor are not continuous all the way down a valley but are interspersed with reaches of denser rock, it frequently happens in times of low water that a stream will be visible while flowing over the less porous drift or shales; and then will entirely disappear in the gravel or in solution cracks for a distance, leaving a dry bed to be succeeded again, when conditions have changed, by a stretch having a visible stream.

Alluvial Terraces.

The main streams while cutting down have also cut more or less laterally, and so have widened their valleys and developed more or less of flood plain along the channels. By these two kinds of cutting, they have in many places carved terraces. Around Georgesville are several in drift. Their forms are not clear cut, but indefinite. Similarly, others occur at the junction of Blacklick and Big Walnut, along the latter near Central College, and again south of Galena; along Alum Creek near Linden, above Parks Mills; near Africa and at Cheshire; and two miles above Worthington along the Olentangy. Terraces have been carved in a like manner in gravels and sands in several places. On

A.—Rock defense at the end of an alluvial terrace, near the gate leading to the State Farm, Orient. The upper rock defends the upper terrace; the lower rock defended a lower terrace, but has now been quarried out.

B.—Rock terrace, Marble Cliff. Looking nearly north across terrace top to drift bluffs beyond.

the Darby at Harrisburg is a fine cluster standing out into the valley from the west side. The stream has repeatedly cut into the gravel here at successively lower levels, but has always swung away and failed to completely remove the deposits. Each time it has left a terrace on a lower level than the last. (Pl. 30 B.) A very similar group juts out into the valley from the east side lapping over the block from the west, so that the stream is obliged to make a very crooked course to get down the valley. (See topographic map.) At the tips of this latter group, limestone ledges are always found acting as a defense for the weaker material. (Pl. 31 A.) If it were not for this rock at critical points, the rest of the gravel must have been cleared away. The defense may be seen in several places at the west end of this group near the railroad bridge and the gateway leading beneath the railroad to the State Farm. These terraces are neat and trim. The front slope of the highest is 28 feet, but to the north where these ledges occur the one big one is divided into three or four steps, too small to be mapped. No such defense was located on the critical points of the Harrisburg group, although repeated diligent search was made; and, in spite of the failure to find a protecting mass of rock, the impression cannot be removed that there are rock ledges here also which may some day be found. Several less definite, apparently undefended gravel terraces occur down stream from these.

In the eastern and southern part of Greenlawn cemetery are terraces, and others occur farther south; still others also occur west of the Olentangy a little above its mouth. These all seem to lack defense and they have not been given the neat, trim form of those cited at Harrisburg. Another indefinite undefended group of gravel terraces occurs along Alum Creek near the Infirmary in the eastern part of Columbus. A very interesting discussion of such terraces as the above, together with the question of the defense, has been published by Davis.[1]

Rock Terraces.

Besides the terraces in drift and alluvium there are many in rock along the Scioto and Olentangy shown mostly in the northwest quarter. (See physiographic map.) These rock terraces occur at all possible levels and in all possible vertical relations to the limestone formations into which these streams have cut. The Pennsylvania railway station of Marble Cliff is on one of these terraces. (Pl. 31 B.) At Dublin, the terrace on the east side is 30 to 40 feet above the water and 20 to 200 yards wide. Three to four miles up stream, a large terrace stands about 80 feet above the river. This is the highest, and the lowest is now partly below water at high stages. They have been described in a recent paper[2] from which the following summary and conclusions are in part borrowed.

[1] Davis, W. M., Bull. Mus. Comp. Zool., Geol. Series; vol. 5, pp. 282-346.
[2] Hubbard, G. D., Ohio Naturalist, vol. 9, (1908), pp. 397-403.

All rock terraces descend down stream, and most of them descend toward the river. Almost every terrace top is nearer the river level at its down stream end than at the other, hence it follows that the grade of the stream has been reduced since the terrace was made. And further, an analysis of the slopes of the various tops shows that the higher ones descend down stream most rapidly, and the lower ones but little faster than the present water level. The average fall of the Scioto at present across the Dublin quadrangle is about 7 feet, and of the Olentangy is 5½ feet, bee-line distances. The upper terraces fall twenty feet in a mile and some of the lower ones ten feet or even a little less. This relation makes it quite evident that the present stream flowing in the same direction made the terraces.

In harmony with the slight eastward dip of the rock strata and the customary streamward slope of the terrace tops, those on the west side are usually structural plains, while those on the east side commonly are not.

The terraces are confined to country whose surface rock is limestone, or limestone with a very little shale cover. The shale alone seems not to be well adapted to terrace formation. Occasionally in the lateral valleys, good terraces are found consisting of Ohio shale from which the thick drift cover has been removed. The shale proving a much tougher material than the drift, the stream has, to date, been unable to make nearly as wide a valley in it as in the drift above. That these shale terraces are largely due to difference in the relative rate of weather ing in the shale and in the drift, and not to lateral planation by the stream, is shown by the fact that, in the two or three instances where such terraces appeared, they were similar on opposite sides of the stream. This condition is never true in the limestone terraces. Rarely is there a place found with a terrace on each side, and when opposite terraces do occur, they are of very different height.

That there is neither harmony nor system in the height of the terraces seems to point to the normal cutting of the stream without rejuvenation as their cause. They are not systematically at the top of the limestone, as if due simply to the encountering of rock, but sometimes near the top and sometimes way below it. Nor is there any gradation in the height of the terraces. A high one may be both succeeded and preceded by a low one, or any other succession may exist. The stream is not a systematically meandering one, hence the terraces have no crescentic fronts and terrace cusps. Nor are the terraces due to any rock defense, as are the alluvial terraces cited above. For these two reasons, they lack the neatness and the definiteness, the conformity to pattern, often associated with alluvial terraces. The streams were degrading streams but at the same time were doing a little lateral planation. Hence, when cutting down in the rock they have migrated a little laterally, and have left, as they withdrew, a gently sloping terrace

top with an alluvium cover. Occasionally, it has happened that the stream after swinging one way, has come to swing in the reverse direction, thus partly planing off the first terrace and leaving another on the opposite side at a lower level. Had the ratio of down cutting to lateral cutting been greater, the terraces would have been relatively higher and narrower, and probably they would have sloped streamward more.

The terraces are of marked economic importance, offering good roadways above flood waters, and good building sites above the fertile flood plains, but not so far away as sites on the uplands must needs be. Springs frequently occur at the back side of the terraces, making them still more desirable for residences. The Pennsylvania railroad (Indianapolis division) finds on the Marble Cliff terrace an easy grade from the flood plain in West Columbus up to its bridge near the station and across to the undissected upland west of the Scioto. Finally, most of the limestone quarries of the area are in these terraces, because of the excellent opportunities offered to get at the rock.

Other rock terraces occur along the Big Darby. One is two miles south of Georgesville on the west side and just south of a large alluvial fan. Its top is twenty to twenty-five feet above the water. This is the only one along the Darby large enough to show on the map. A little gravel or alluvium continues the rock terrace at each end. Between this point and Georgesville, a number of miniature rock terraces occur from water level to about 20 feet above. The Darbys have cut through the drift in many places, but have only begun here and there to cut in the rock, hence their terrace series are in a much less advanced stage of development than are those of the two larger rivers. While its terraces are not large and are never far above the water, it seems probable that the time will come when the Big Darby will have so far cut into the rock that its valley too shall be ornamented with terraces of limestone.

Growth of Lateral Valleys.

As the main streams have enlarged their valleys both downward and laterally, and the side valleys have developed, the streams have been getting more and more complete possession of the till plain. A sag or kettle in the plain collects water. When the depression is full, it overflows and the overflowing water carves a little channel away to some growing tributary. Thus, the tributary is lengthened by the addition of a new section. When the addition is completed and water drains from beyond the sag into and through the latter without halting, and on down to the larger stream, this whole lateral valley in which it flows will be narrow at the head, wider where the sag is traversed, and narrow again below it. Many laterals in this way now pass through what were once sags or kettles in the till plain or moraine, and hence

are not systematically larger from source to mouth; nor are they symmetrical. They vary in width, and the stream often lies close to one side with no evidence of its having swung across the valley.

By Springs.—Springs often lead a valley headward. Water flows away from the spring and joins a stream, developing a little valley as far up as the spring. Then earth falls repeatedly into the head of the new valley and is carried away. By this process, which is known as sapping, the valley is elongated, the spring leading it along the underground water course that supplies the spring. A fine example of this phenomenon occurs a mile or more below Harrisburg in the west bluff of the Darby, where a valley a hundred feet long and fifty feet deep has been made by a spring issuing from the contact of new and old drift.

By Headward Erosion.—The universal process of headward erosion is responsible for most of the elongation of tributary valleys. Much has already been done toward obtaining complete possession of the uplands. Yet hundreds of square miles of plain still exist which have been practically unmodified by the streams. Man is aiding the work by making open ditches through the fields and preventing erosion by underdraining with tile. As one follows up the young lateral valleys, their floors in each little tributary are found to approach nearer and nearer the level of the till plain. Usually the rock disappears and the stream flows on drift some little distance below the sources. (Pl. 32 A and B.) Finally the valley, like a vanishing trench, runs out and leaves the traveler upon the upland. This is the level till plain previously described. Thousands of little rivulets form upon it and creep out toward some tributary head, then leap over a little drift fall, a few inches to a few feet in height, and start down the ravine. These tiny rivulets by eating at the ravine heads and pushing the tiny falls back are putting the streams in possession of the plain.

So little progress have the streams made in developing the drainage system that the topography is designated as young. The valleys both of the major streams and of their laterals are in a youthful stage of development, as is evinced by the relatively steep slopes of the valley walls; the narrowness of the valleys; the barrenness of the rocks of the valley walls in many places; the broadness of the interstream areas which contain the inconspicuous, indefinite divides; narrowness, in many cases absence of flood plains; the steepness of the grade of the channels; the paucity of tributaries, and the failure of the drainage system yet to have gotten possession of much of the uplands. Different degrees of maturity are reached by different streams. The major streams, especially along those parts working in drift, have the most mature valleys. In fact, in some places the development is so advanced that the term submature, almost mature, might be applied; while some of the upper ends of the tributaries and upland farm streams occupy valleys in such

A.—Headward erosion valleys as seen from the Baltimore & Ohio Railroad north of Orient. Two branches meet in the center of the field.

B.—A view farther up the left branch seen above.

extreme youth that there really is no valley at all—only a channel, whose slopes are so short vertically and so little worked upon by the streams that they have not yet reached the steepness considered characteristic of youth. These valleys are too young even to have steep slopes either in their walls or in their channel floors.

Effects on Till Plain.—Two pictures will serve to illustrate what the streams are doing for the plain in the way of dissection. Southwest from Harrisburg a good macadam road leads toward Mt. Sterling. Careful construction and considerable grading have given a good easy highway. The photograph for Plate 33 A was taken about one and three-fourths miles out from Harrisburg, looking back along the road. It shows the ups and downs of this part of the road which are due to the unevenness of the plain, unevenness developed by erosion of small streams leading southeast to the Darby Valley. These streams cross the road nearly at right angles. The plain here may be said to be broken. The picture on Plate 33 B was taken two and one-half miles farther southwest looking northeast, and shows the extreme levelness of this unclaimed portion. Telephone poles, the view of the carriage and the house at the end of the road, show vividly how extremely level and unmodified the plain here is.

Varying Width of Valleys.—A great many of the valleys, notably the gorges, show remarkable variations in width even within short distances, variations which can be traced almost entirely to local causes. Some of these have been noted in other connections on previous pages. One of the prettiest illustrations of this variation is found in the valley of the first stream on the left of the New Albany pike about two miles out from Gahanna. (Fig. 15.) The upper part of the valley down nearly to the town line road is narrow, bordered with practically continuous outcrops of Mississippian sandstones and shales. Then for more than half a mile the valley opens out four to six times as wide and is grassed over completely. No rock can be found in any part of this section, but farther down stream the valley narrows down again for one-fourth mile, and the same shales appear constantly. The variations here are due to the fact that the present valley crosses an earlier buried valley. Where the present valley is in rock, it is narrow; but where the stream has had to remove only drift, filling the old valley, it has been able to open out a wide one. Northeast of Reynoldsburg are several similar illustrations. Between Columbus and Worthington, several of the valleys largely in the black Ohio shales exhibit the same peculiarities. There is usually an abundance of boulders in the stream bed at these wider places.

From Lewis Center westward, a valley leading down to the Olentangy has almost continuous rock outcrop in its walls after the rock is once reached. But the valley is first of moderate width for some dis-

tance west of the electric car line, then it becomes wider for a short distance, then narrows to a rock gorge at the bottom and so continues to the river. Examination reveals the fact that in the upper part the bed rock is a black tough formation described in the first part of this bulletin as the Ohio shale. In the middle part is a soft, easily eroded, bluish rock called the Olentangy shale; and by the time the lower part of the valley is reached, the stream has cut through both of these to

Fig. 15—Topography and rock outcrops (in heavy black lines) in the vicinity of Gahanna and Rocky Fork.

the hard Devonian limestones below, and here it has been able, so far, to carve only the narrow gorge. Many streams tributary to the Olentangy and a few leading to the Scioto illustrate this type of variation.

The large streams as well as the small are subject to these phenomena. At Georgesville, the Darby valley is broad in drift, but a mile south of town, the stream encounters the limestone, and the valley is pinched up almost to a gorge. The Scioto from Arlington and Grandview southward is a broad open valley, but northward it becomes a veritable gorge throughout the whole area; because downstream it is in drift and alluvium, but upstream in the limestones. The Olentangy is in drift

A.—Effects of headward erosion on the till plain southwest of Harrisburg. Sags in road mark places where little valleys have been cut.

B.—Absence of erosion on till plain near Derby, Ohio. Road is very level.

from its mouth nearly to North Columbus; then in Ohio shale, in part at least, nearly to Worthington; in drift here, for two miles;[1] then in the shale, nearly to the north county line; from whence it is in limestone to Delaware. The valley gives expression to these variations in material by presenting corresponding variations in width and general maturity of form. A comparison of the size and depth of the Olentangy and Scioto valleys also shows the effects of rock resistance. Although the Scioto is three or four times as large as the Olentangy, it has a much smaller and even shallower valley in the limestones than the Olentangy has in the shales.

Variations in valley widths have been noted in a few instances where the above conditions do not apply, usually at junctions of streams, or at turns where lateral planation has been specially active.

Many streams run their whole courses in similar rock materials. Rattlesnake Creek is in the Berea or Cuyahoga sandstones almost its whole length; and it has carved a narrow steep-sided gorge which might well be called a box canyon, because its sides are so steep and its walls make such clear cut angles with both the flood plain below and the till plain above. The gorge lies like a trench cut in the plain and is sparsely timbered. A similar valley, but one carved in drift, is that of the Darby at Orient. It is now a hundred feet deep, but many times as wide as Rattlesnake valley; yet its bluffs are as steep as the drift will stand. The Baltimore and Ohio railroad does not descend to cross it, but traverses a long viaduct ninety feet above the flood plain.

A pretty valley entirely in drift leads from a mile or so west of Linworth eastward to the Olentangy. Nowhere is the rock revealed in it. The valley is open; its slopes gentle, except where recently undercut, grassed over or under cultivation; its floor is evenly graded, and the whole valley is beautifully smooth. Similarly, the south valley that leads to the Scioto at the Columbus Fishing and Gun Club, has no rock exposures, but is mantled and smoothed with the drift until it presents most attractive curves and slopes; while the north valley is a rock gorge all the way. Such comparisons as these show clearly the difference between age in years and age in development. Valleys in rock are very young, while those in drift are many times as far advanced; yet in years, all those mentioned are essentially of the same age.

Landslides.

Many of the more youthful valleys have had landslides and now present characteristic topography. In most cases, the sliding has been due to ground water producing springy conditions in the drift, occasionally in rock. About one and one-half miles southwest of Galena along the valley road are well marked landslide surfaces in drift

[1] Orton, Edward, Geol. Survey Ohio, vol. 3, p. 598.

over Ohio shale. Several slides in relatively recent times have occurred a mile or so south of Georgesville along the west bluff of the Darby. On the same side, some four miles below Harrisburg, are many more large drift slides. Some have a growth of young trees twenty-five or thirty years old upon them. Rock slides are known in the gorges tributary to the Scioto and Olentangy. Usually these affect the stream only a few years and are then all washed away, but a few persist for many years.

Water Falls and Rapids.

Many of these youthful valleys have rapids and a few of them have falls, which have gained a little local notoriety. Hayden Falls is perhaps best known. (Pl. 27 B.) The water leaps over a layer of the Columbus limestone after cascading over several layers of the less resistant limestone above the hard one. The fall, which started at the bluffs of the Scioto, has retreated upstream only a short distance. Recently, the water has ceased during low stages to go over the falls, but drops down into joint cracks some distance above the fall and finds its way through them out to the Scioto. Many streams during low stages follow this peculiar habit of losing themselves in cracks in the limestone near their mouths, and then emerging nearer the river or even below river level. In the case of Hayden's or any other stream with a fall from which underground passages have withdrawn the waters, the fall ledge constitutes a natural bridge; and if the lower passage becomes large before the span collapses, a very attractive bridge will result.

Indian Run entering the Scioto at Dublin has two branches uniting half a mile above its mouth. Falls, having retreated from the Scioto bluff up to the junction, divided, and each part has now migrated some little distance up its fork. The fall here has retreated much farther than that at Hayden's, possibly because there is more water. Just west of the new Casparis quarries, three-fourths mile up stream from Marble Cliff and west of the Scioto, a small stream enters the river with a 30-foot fall over the topmost layer of the Columbus limestone; and the same stream has rapids for a hundred yards or more, higher up, over the thin-bedded Delaware limestone. This fall has retreated a little over 100 feet from the Scioto bluff. Slate Run on the east side of the Scioto a mile and a half above Fishinger's bridge, has a small two-step fall over a layer of the usual fall-making limestone. This fall has retreated nearly one-fourth mile from the Scioto bluff. Opposite Hayden's Run is another small fall. Several others occur in the laterals of the Scioto, and a few insignificant ones in the laterals of the Olentangy.

Some falls occur over the top layer of the Columbus, others over different lower layers of the same formation. While the falls are over a layer twenty-five to thirty feet below the top of the Columbus, oftener than over any other, no layer seems to be preeminently the fall-maker. Neither is there any system in the distance the falls have retreated. Some streams have none. The Scioto itself has no fall, but in places has little rapids. It is on the Columbus limestone continuously from

Marble Cliff, northward eleven or twelve miles into Delaware County, where it has cut entirely through the formation to those below. All the lateral streams are in gorges in the limestone, and the upper Scioto has a gorge beneath the top of the Columbus formation. The latter has entirely passed the fall stage, if it ever had falls. Their presence in the laterals would suggest that they may have occurred in the Scioto; but the facts, that there seem to be no common fall-maker and no uniformity of retreat, would indicate that in the Scioto there probably never was more than rapids, unless for a short time at the southern limit of its gorge, and even there it is believed to be improbable.

Many streams have rapids over limestone or shale ledges, and occasionally over the old drift and over beds of residual boulders left by the stream after sorting out the finer movable elements of the drift.

Flood Plains.

A brief survey of the physiographic map or a little observation in the field would show that there is a great variation in the degree of development of flood plain along different streams and in different parts of the same stream. The Scioto has the widest flood plain and is the largest stream, but it also has a very narrow plain in places. For example, about one mile south of the Duvall road across the river, it is less than one-fourth mile wide; while at the Hartman farm and northward to West Columbus, the plain is one and one-fourth to over one and one-half miles wide. This is all in drift. From Marble Cliff northward, the flood plain is quite limited, often wanting, usually too small for cultivation. From Marble Cliff down, the stream is not degrading perceptibly, but is cutting laterally. Up stream the lateral cutting is still very slight. Undoubtedly, the ratio of the lateral to the vertical erosion in recent times is the variable upon which the flood plain width depends. Streams in drift or soft shale, even though small, are cutting laterally enough to have developed flood plains. The plains are made of alluvium, with large recent fills in places. (Pl. 34 A.) In some localities the alluvium overlies rock platforms; in others it overlies gravel; but in either type the deposit is there because of slight aggradation during lateral swinging. In this swinging the stream cuts out rock, drift, or previous deposits from one side, and lays down material on the other, coarser materials near the bottom and finer upward to the topmost level of the highest flood, which is manifestly the limit of stream aggradation. The surface of a newly finished section of flood plain is a little below the level of the plain being cut away, which may give a measure of the rate of down cutting.

Meandering and Abandoned Channels.—The lateral cutting is sometimes associated with meandering, and where so related abandoned

channels, oxbows, and cut-offs occur. One and one-half miles above Harrisburg, the Darby has abandoned a mile of channel in the flood plain. The southern end still contains a pond or lake. The channel northward remains open but is not now swampy nor, except in flood, water-covered. Similar abandoned channels can be found along all the larger streams and many of the smaller ones.

Sand Bars.—Sand bars occur in many places on the flood plains, some five to ten feet above them. These were built during high stages of water. Two examples may be mentioned. One is two miles north of Harrisburg in the Big Darby valley. It rises ten feet above the plain at its north end, but descends southward and blends with the plain at the lower end. The other is in the Scioto valley a mile or so south of the mouth of Big Walnut. This one is about a mile in length, but the former is much shorter.

In a few places, the stream is now braided and aggrading. One to one and one-half miles downstream from Orient, the Darby is so conducting itself because of the undercutting, slumping and rapid erosion of the tumbled waste, upstream. More waste falls in than the stream can carry away, hence it aggrades therewith. The larger streams especially are not now doing much down cutting, as is made plain in places by the large development of flood plain and associated features. The plain is level and only a little above the stream; and there are upon it large alluvial fans. Now the making of these fans must have required considerable time; and they could not be started until the flood plain was finished and the stream had swung away. During their building, the stream has cut down scarcely at all. Hence, it is argued that the streams are not at present actively degrading. Further evidence on the amount of erosion now being accomplished by the Scioto is furnished by studies at Columbus, where the dredging for gravel is being carried on. Gravel is removed from the channel of the stream for commercial purposes, and the depressions resulting do not fill with gravel, nor even with sand, but with mud, showing that the river does not bring to these places any coarser materials.[1]

A very pretty feature is the artistic blending of the valley wall with the flood plain. This is most pronounced along the larger streams in valleys in drift, but it may be seen along almost any stream where no recent undercutting has occurred. It is mainly due to the washing and falling in of waste from the valley walls.

In many places along the larger flood plains, artificial levees or dikes have been constructed to keep the water off these flood plains. These are much narrower and have steeper slopes than natural levees.

[1] This item was furnished orally by Mr. A. L. Smith, of the Geol. Survey of Ohio.

A.—Deposit of sand laid on flood plain of Olentangy River on Ohio State University farm. This delta-like form is thick enough to cover corn stubble, and was all laid during one high-water period of thirty hours. *(Photo by J. E. Hyde.)*

B.—Gently sloping alluvial fan at the mouth of a ravine near Grandview. Several such fans on the Scioto flood plain can be seen from the Arlington car looking north. The ravines furnished the waste now laid in the fans.

Alluvial Fans.

A glance at the physiographic map will show to what an extent large fans have been formed, but nothing less than a trip along a flood plain can reveal the beauty and abundance of the little fans which universally adorn them. Alum Creek, Big Walnut and, to a less extent, the Olentangy present the large fans. Typical examples may be seen opposite Westerville, opposite and south of Pinhook, and at the mouth of Big Run north of Clintonville. A single large lateral has a simple fan, unless it has been eroded away by the main stream; but a group of laterals, as opposite Africa and again two miles further upstream, build a series of fans blended together at their sides, constituting a compound fan. Sometimes a large lateral of low grade has a large fan, and a small lateral has a small steep fan on the large one. Such a combination occurs on the Olentangy flood plain east side, a mile or so north of the Franklin-Delaware county line. Other fans occur on terraces, as does one along the Scioto on the big terrace east of the river, and two miles above the storage dam. Even up many tributary laterals, such as Springwater and Glenmary runs, the Lewis Center valley and Rocky Fork, fans have been made by their laterals on flood plains and sometimes on terraces. The younger and steeper the lateral that made the fan, the steeper the fan. Some were built in the youth of the laterals; and now in a slightly more mature stage of the lateral, the fan is found to be too steep, so the stream has trenched the fan, deeply at the top and less at the margin, and with the waste removed has built a secondary fan at the margin of the first. Nearly every little ravine leading down a bluff from the uplands and mouthing on a flood plain has a fan at its mouth. Literally, hundreds of these fans may be seen in a few days of travel along valley walls. A ride to Arlington on the Grandview car will suffice to show several very fine examples with radii of 100 to 500 feet and altitudes of five to fifteen feet. (Pl. 34 B.)

Succession of Events.—Some fine lessons in the succession of events and time consumed in making a series of features may be worked out with a study of fans and flood plains. Suppose one finds a group something like that shown in Figure 16, which is a conventionalized sketch of an actual problem found in one of the minor valleys of the area. There were in the field the upland (a) in which the valley had been carved, the east wall (b) of this larger valley, a rock terrace (c) to the left, covered with alluvium, and preserved since the valley was about half as deep as at present. Then there were two alluvial terraces with rock below, (d) the older on the right and (e) the younger on the left, made when the stream had degraded to a still lower level; and (f) the gravel and sand deposits of the present stream level. Three fans occur, a primary (g) on terrace (d), and a secondary (h) in front of its predecessor, and another primary one (i) on the lower plain (e). The gorges (j) which furnished the waste for fan (g), and (k) similarly related to (i), differ in form in accordance with their respective ages.

One of the last features made is the lower flood plain (f), which has willows and sycamores of good size upon it. Another recent feature is the secondary fan (h), which now has a walnut tree upon it over fifty years old. Not much material has been laid around this tree as it grew, hence fifty years ago this fan was nearly as it is now. How long it took to build (h) cannot be de-

termined, but certainly centuries, if so little has been done while a fifty-year tree grew. Fan (g) was completed before (h) was begun, because it was made by the same stream when the latter required a steeper slope and was aggrading its course across (g). After the stream ceased building and began to degrade, it trenched (g) and made (h) of the products. The change in habit of the stream across the fan is brought about by the reduction of the grade in gorge (j). Fan (g), which must have required much time to build, could not have been started prior to the completion of flood plain terrace (d) and the swinging of the stream away from this east bluff (b); and since that time the stream has been able to cut down approximately from level (d) to level (f), or three to four feet. Between the completion of terrace (d) and the present, the stream has swung to this east valley wall a little farther north and effaced part of the terrace, then swung away, leaving the lower flood plain terrace (e); and since the completion of (e) fan (i) has been made. It is smaller, its gorge is more youthful and it has not been dissected as has (g), all of which indicate its youth and are in harmony with its position on

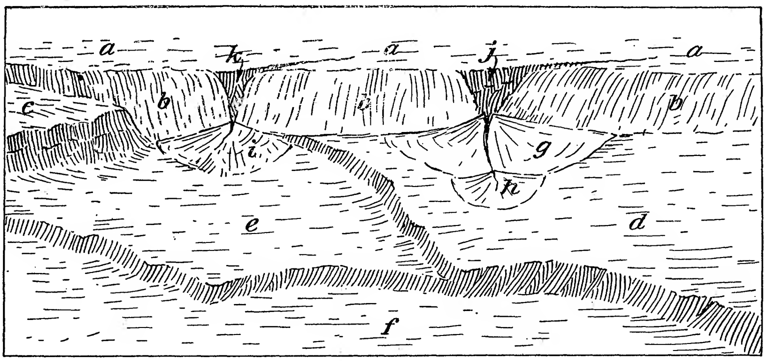


Fig. 16—Birdseye view in block diagram of a group of terraces, fans, and related features, selected for a study in physiographic chronology.

a younger flood plain terrace than that beneath fan (g). Long before the making of any of these features whose development has required so much time, the stream swung off of the terrace top (c) and then returned on a lower level and trimmed its front slope. This present front slope is too steep to date from so remote a time; hence, we may infer that the stream retrimmed it when it swung east and made terrace (d) or terrace (e). And the main valley, carved in the upland till plain, must have been as deep as terrace top (c) is below the upland when that terrace was begun. It would now be possible to state the time of making any one of the features with reference to that of any other, and to state their ages in relative terms.

That the fans were made by the streams leading out of the ravines across them, may be inferred from a long line of evidences. (1) The material of the fan is the same as that removed to make the gorge. (2) It is distributed and deposited as a stream emerging from a steep-floored ravine upon a level plain would do it. (3) Fans are almost universally present at the mouths of ravines unless for obvious reasons it is impossible for one to exist there. (4) Fans do not occur in other kinds of places. (5) Fans in any given locality are consistent in size, form, and materials with the ravines above; i. e., large ravines have large fans at their mouths. Ravines with easy grades have fans of gentle slope and fine material and vice versa. (6) At certain seasons one can see the stream in the ravine pick up materials, transport them and lay them on the fan.

Fans have some economic significance. They make easy grades for roads from the flood plain up the lateral valleys. The electric car line from Columbus to Arlington uses one to help get from the Scioto flood plain up to the till plain level from which the "grandview" is had. In

many instances, they have furnished building sites safely above the floods or malaria of the lower flood plains upon which they rest. They have been taken for pleasure shacks, for stock yards with the pasture below, and for sawmill sites while the flood plain and hillside lumber was being worked up.

Changes on the Till Plain.

In most respects, the unclaimed parts of the till plain have suffered during post glacial time the least alteration of any part of the region. Yet, even on these level upland areas there has been considerable change locally. While the valleys were being carved, terraces trimmed out, flood plains constructed and adorned with fans, and lateral valleys developed, surface wash has carried a little of the finer materials from the higher swells of the till plain into the low places and leveled them up, at the same time leveling down the swells. Thus, many kettles too have become more or less completely filled. Some kettles, however, containing water, have developed swamp conditions and to this day are haunts of the blackbird, muskrat, crayfish and frog, together with the cattail and sedges. Such swamps can easily be found, and many of them have been mentioned on previous pages. Other kettles have developed peaty conditions and today present young peat bogs. Probably the best example of this feature occurs about half way between the Scioto and the Olentangy rivers, a little west of Seagrave and four and one-half miles northwest of Columbus. Others are to be found just west of the Scioto on the upland plains both north and south of the Franklin-Pickaway county line. Recent effort has been made to drain some of these.

Peculiar Valleys.

1. **Rocky Fork Above Gahanna.**[1]—Several valleys merit special consideration because of the apparent abnormalities which they present. One of these is that of Rocky Fork, which enters Big Walnut at Gahanna from the east. The upper course to a point some three miles from the mouth, is in drift touching rock occasionally. Then the stream is on the sandstones and shales, and has a narrow, rocky gorge for about a mile. At this point the valley widens, rock may be found only on the east side, and gentle drift slopes border a broad flood plain on the west side. (A, Fig. 17.) This continues for possibly half a mile, when the valley again becomes much constricted, and rock in steep cliffs stands on each side. The throat (B) is some 500 feet long, beyond which a broad valley with a valuable flood plain succeeds, and the rock is not found in either valley wall until near the swing-bridge, where the chocolate shales abut against the drift (C). (See p. 250.) The contact is a south or southeast sloping surface, as if the shales had been eroded from that direction to this point, and then the drift put into the valley thus made. (Pl. 27 A.) The branch (D, Fig. 17) has no rock exposed at any point, and wells along the highway eastward even beyond the schoolhouse do not reach rock even at depths greater than the present valley. At the down-stream entrance to the throat mentioned above, and on the east side of the Fork the rock-drift contact is a south facing slope. The little stream (E, Fig. 17) is on rock nearly to the mouth, but the last 600 feet or more is in drift. It

[1] Most of these little problems have been worked over repeatedly by students, but none of them have ever been published.

seems probable after examining the rock distribution (Fig. 15) that the preglacial (or interglacial) valley here bends northward a little from a westerly course and is intersected by the postglacial valley. Possibly the broken line (Fig. 17) may represent the north wall of the buried valley.

More peculiar is the abandoned valley behind the hill toward which the swing-bridge path leads. This channel is over a mile long and from 300 to 1,000 feet wide. It joins the present valley at each end at points less than one-fourth mile apart. The eastern or upstream end (F) is about twenty feet above the present valley flood plain, while the western end is twenty feet lower and not more than eight or nine feet above the present adjacent flood plain. The latter descends some ten feet between the two entrances to the abandoned channel.

It seems probable that Rocky Fork once flowed through this abandoned loop, but at that time it did not take its present course at the suspension bridge. In the course of time, the curve near the bridge where the stream turned north, by undercutting, pushed westward; and the curve, where the

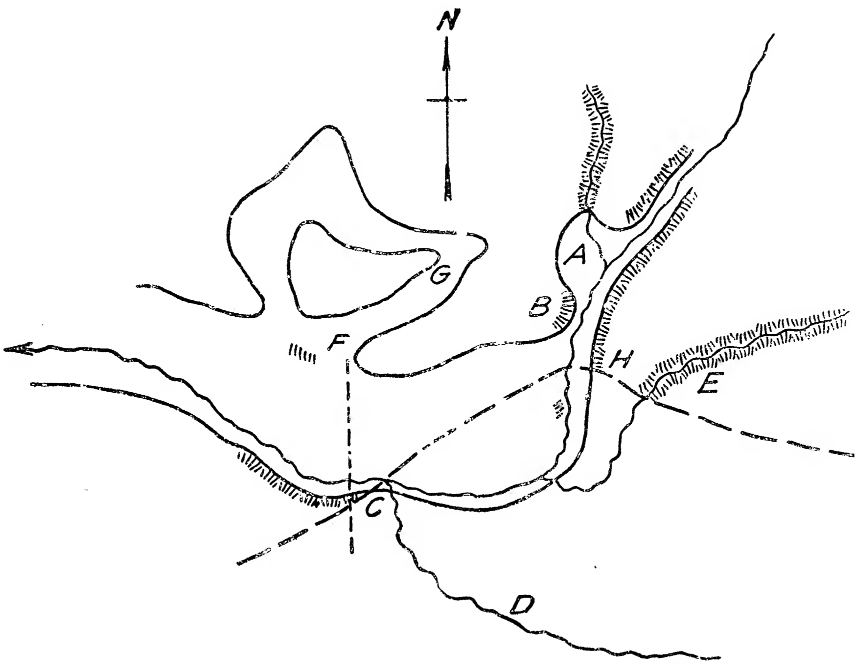


Fig. 17—Sketch map of salient features of Rocky Fork. Smooth line, bluffs, crinkled line, streams; hachures, rock; heavy broken line, probable north wall of buried valley; light broken line, suspension bridge and path.

stream emerged from the now abandoned loop and turned west, by cutting eastward, approached the other curve. When the two curves met, the stream on the west was some twenty feet lower than that on the east side, i. e., equal to the fall of the stream in a mile-long journey around the loop. When the partition between the curves broke, the water abandoned the loop and took the shorter course. In this new course, the stream finally swung laterally and widened its valley to the present limits. Not much down-cutting has been accomplished since this diversion, but the fall at the cut-off has been distributed, and the average grade of the stream in this part has been somewhat lessened.

The main points which lead to this interpretation follow. (a) A marked similarity exists between the abandoned loop and other valleys. It is evidently a stream valley. (b) The slope of the abandoned valley floor is down stream, but with a steeper slope and a higher level than has the present stream. This

condition must have existed, if the stream went through the loop in earlier days; for all the streams in this vicinity have been lowering their beds and reducing their grades. (c) At (G, Fig. 17) the abandoned channel has boulders in it, as have present stream valleys. (d) It is manifestly not due to deposition, although all surrounding valley walls are of drift. The cut-off must have occurred a great time ago, because the new course is now nearly as well matured as other parts of the valley continuously occupied; while the abandoned part has no steep, recently undercut slopes, but all are evenly graded. Moreover, a good-sized fan has been built on the floor of the abandoned valley.

The broad section of the Rocky Fork valley (A, Fig. 17), above the throat, is due to a large curve in the stream now abandoned. This one differs from the one just described, in that the stream cut out all the land in this loop and left no hill. The plausibility of the explanation above for the isolated hill and abandoned valley seems greater when it is noted, that, if this loop

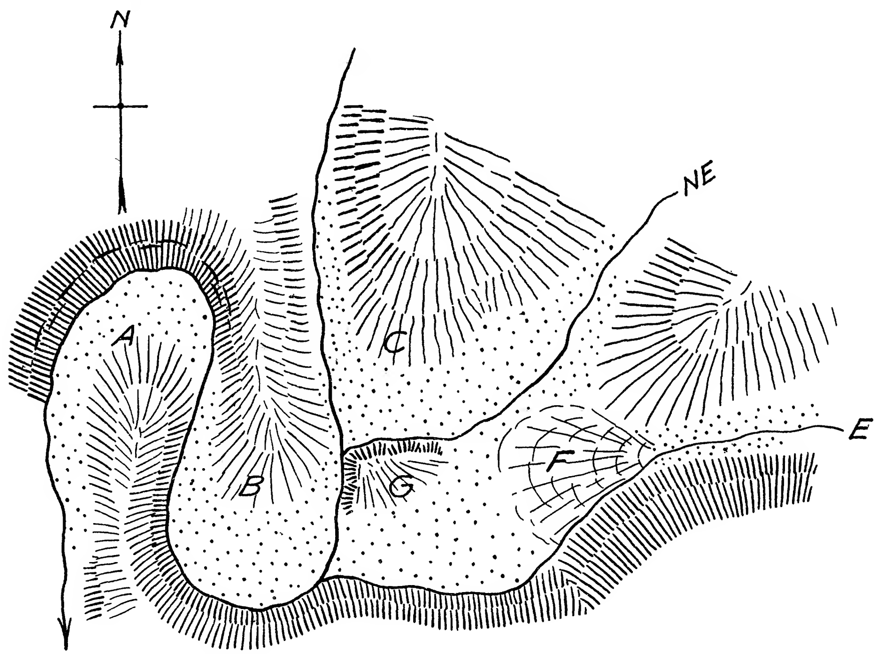


Fig. 18—Hachure map of region in north branch of Lewis Center. Stippling more or less level flood plain deposits. Hachures, rock slopes of various degrees of steepness, usually mantled.

(A) had cut through to (G) before the other loop had cut itself off. the throat would have been deserted and the peninsula-like mass of land now carrying the tree cliff would have become the isolated hill, while a horse-shoe-shaped, abandoned channel would have extended from (A) through the throat (B), past (F) to (G). Undoubtedly, the absence of rock in some portions of this valley, due to the encountering of the buried valley, has been a factor in the development of these peculiarities.

2. Lewis Center Valley. — Two rather unusual features in this valley merit mention. They are both to be found up the north branch fully half a mile from its junction with the east fork. In this vicinity, the valley, wholly in the black shale, widens out to two or three times the width, either above or below the place, and the stream describes two closely compressed, deeply intrenched meander loops. An isolated rock hill stands here in the valley between the mouths of two laterals, which enter from the east and northeast. The problem is the explanation of the isolated hill (G, Fig. 18). The streams must have started with easy grades on the till plain, and as time went by,

they incised their channels into the rock little by little. Lateral planation perpetually on the same side during the long continued down-cutting has accomplished results which the stream could not attain, cutting alternately on one side and then on the other. The big stream loops, which swing around curves (A and B), have enlarged and slowly slipped off the spurs, which now extend far out into the loops. The necks of these tongues are narrowing, and may some day be cut through. Streams (NE) and (E) arriving from their respective directions, entered the main stream with a narrowing ridge between them. Each stream has gradually slipped southward (NE) over spur (C) and (E) over spur (G), just as the loops slid off of their respective spurs, leaving similar long, gentle slopes descending southward; and each has undercut on the south side, making a steep cliff. Stream (E) has been more migratory than the others, for it and stream (NE) have succeeded in cutting out the rock between them near (F) and thus have isolated the hill from the end of the spur between them. Since the isolation both the main stream and (NE) have been planing off the hill; and (E) has deposited material for quite a fan (F), as it comes out of its gorge upon the flood plain.

The other unusual feature is a hanging valley and cascade a little farther up this same branch. A stream with little entrenched meanders comes down from the west and leaps over an undercut bluff ten or twelve feet high, into the larger stream, while a similar little valley with curves like those of the entrenched meanders, extends from near the fall along the bluff southward perhaps a hundred feet. This short valley does not connect with the small valley from the west, though at one time it may have done so; but both ends of it connect with the main valley. It has been suggested that this short valley represents a former course of the main stream or the course of a part of the main stream. It seems more probable, however, that when the main stream had the course of the broken lines (A and B, Fig. 19), the little stream did not terminate at its present mouth (C), but turned on land now cut away, and passed through the abandoned short channel and entered the main stream near (D). The same undercutting by the main stream which tapped a meander of the lateral, cut away the former mouth of the stream from D to D/. This explanation is supported by the following facts: (a) The main stream manifestly has been, and is undercutting. (b) The meanders of the lateral and of the abandoned channel are similar as to size and stage of development. (c) The abandoned channel descends from (C) to (D) at about the same rate as does the present channel of the little stream. That the mouth of the lateral has been undercut is shown by the fact that it is now, at (D), a foot or more above the main valley floor. A formula for the height of the hanging valley in a case of this kind may be stated as follows: The mouth of the lateral valley now hangs as much as the fall of the lateral from the new mouth to the old, minus the fall of the main stream between the same points and the amount the lateral has cut down since the capture, and plus the amount the main stream has cut down in the same time. Certain obvious substitutions must needs be made, if the main stream has aggraded; but such a variation would be rare, because an aggrading stream is not liable to undercut in this manner.

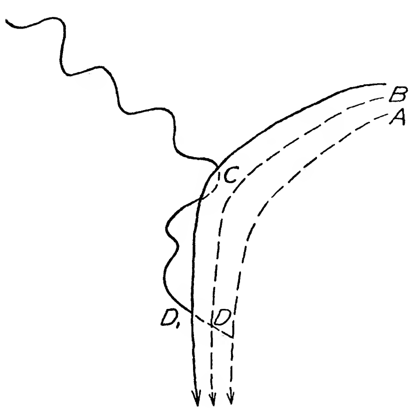


Fig. 19—Map illustrating one method of stream capture shown in north branch of Lewis Center Run.

In the valley of Glenmary a short distance below the electric line, is a case very similar to this, except that just before the streams had completed the work, man aided by a little cutting and filling.

Back at the steep bluff north of loop (A, Fig. 18) a stream enters in a hanging valley much like the above; but in this case the stream formerly entered farther up stream (Fig. 20), rather than farther down stream, i. e., along the broken line. The formula for the height of the fall or amount of the "hang" of the lateral, could be stated for this case also.

3. Solution Work.—Sinkholes, mentioned in another connection (p. 254), are very numerous west of the Scioto and northward from Marble Cliff (Fig. 21), and a considerable number of them occur west of the Olentangy from two miles south of Hyattsville to the northern edge of the quadrangle. The solution work accomplished by ground-water moving along joint planes, to which these sinks are due, must have occurred before the last advance of the ice and possibly before any advance of it. They certainly represent a long period of ground-water erosion, and could not have come into existence while the striations on the rock surfaces nearby have remained almost untouched. That they are limited to the areas sketched above is true, because only here has the post-glacial surface water found its way through ready-made passages to the rivers. However, subterranean passages of the same sort are known in many other places, and no doubt they exist all over the area immediately underlain by the Devonian limestones.

Their relation to valleys is illustrated in an interesting case a mile north and a little east of Hyattsville. The first run south of the east-west highway, leading down to the Olentangy, has a big sinkhole into which the drainage for over half a mile pours. The valley increases normally in size, depth and maturity down to this point, where it is a broad, deep valley with a large capacity for water. But immediately below the sink, the valley is ten feet shallower, and there is not much channel. Water all goes down the sink under ordinary circumstances, and there is none to make a channel below.

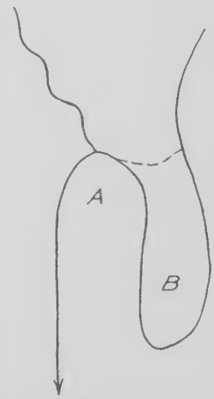


Fig. 20—Map illustrating a second type of stream capture in north branch of Lewis Center Run. Same part of stream as Fig. 18.

Fig. 21—Partial view of a sinkhole in limestone on the farm of Mr. Schrumm west of railroad bridge at Marble Cliff. Horizontal layers of limestone show from bottom of pit nearly half way to the top. The dark place at the right of the stones marks the entrance to a passage leading westward many feet along a joint plane.

During rainy weather, water collects in the hole and goes down as fast as the passage will permit; but if the pit fills full, it sometimes requires a day or two for all standing water to drain away. The water is said to emerge and enter the Olentangy by means of a spring at low water stream level. Another similar large sink in a valley occurs about a mile further south. A third fine example is just south of the road leading east, one and one-fourth miles south of Hyattsville. Here, the sink takes all water collecting in the channel above it. The valley below is not so deep as above, and is beautifully graded and grassed over and has no channel at all. Side valleys have large fans spreading out across the valley floor. Farther down, a tiny stream again begins in the valley and flows out to the mouth at the river. Water must have gone all the way down the valley once, and after the valley had reached about its present size, the underground passage was found, which has been used ever since.

Rows of sinks sometimes occur with no surface connection, but with unquestioned subterranean communication. Other sinks occur with valleys leading to them and absolutely no sign of one beyond. Such is the case a mile or more northwest of Dublin, near the schoolhouse. Undoubtedly, a considerable number of the springs known along the western Scioto bluffs are outlets for sinkhole drainage, and obviously should be avoided as drinking places.

Valleys and Deforestation.

A century ago, nearly all this region was more or less densely forested. Valleys had become adjusted to that condition. The change to the present farming condition has brought about considerable alteration in many of the streams and corresponding changes in the valleys. If timber is removed, water moves over slopes more freely and carries waste down to valley floors faster than streams can remove it. Hence a considerable number of valleys have been aggraded and do not show rock at the bottom. Several of this type lead into the Olentangy from the west, a little south of Hyattsville, and others lead into Alum Creek opposite Africa. Those thus aggraded are level floored in cross-section, and, if pastured and kept clean of brush and weeds, present beautiful grassy slopes and floors. Many still forested have not been aggraded, and others deforested and now reclothed with new growth of timber are being re-excavated. Those in a brushy condition and unpastured are often springy and swampy because of plant interference with drainage.

Relation of Present Scioto and Olentangy to Preglacial Valleys.

It has long been believed that this region held the key to the problem of the preglacial Scioto or of the drainage of Central Ohio, and during all this work care has been taken to find, if possible, a solution to this problem. Many items have been collected which have a bearing on the problem, some directly, some rather remotely; and it will be the purpose of this section to set down in order the facts and arrive at a probable conclusion.

It is well known that the present topography descends southward over nearly the whole area, and westward over a small strip along the eastern side. The only exception to this last statement is between

Pickerington and Waterloo where the surface averages about 800 feet. It has been determined that the rock topography also descends in the same directions. (Pl. 26.) Reference to this map shows the rock altitudes across the north, so far as known, to be uniformly above nine hundred feet except for two well records one and one-half miles apart between the Scioto and Olentangy. This statement excludes the present valleys of the Scioto and Olentangy rivers, together with Alum and Big Walnut creeks, the first three of which are in this section on rock and have bed rock high on both sides, indicating that they are in valleys of their own making at these parts; while the latter seems to be entirely walled and floored with drift, but has cut only to 900 feet here. It will be shown that the present valleys are the work of the streams in them. Therefore, it does not seem possible that any stream of these larger sizes could have come into the area from the north, and certainly none could have left there.

Along the western side, many well records and rock outcrops give figures for the top of the rock as shown on the map. (Pl. 26.) No reading along the border is low; but one to four miles in from the border and near the northwest corner of Franklin County, several well records show rock at or near the bottom. In all such wells the rock surface is between 700 and 800 feet above sea level. Rock topography east and south of them shows no place so low by scores of feet. Since there must be an outlet for the region somewhere if it is stream made, it must be sought to the west and southwest. Three wells in this group show rock surface lower than the present Scioto, which is now in a narrow rock gorge in this latitude. The supposed course of the drainage for this pre-Wisconsin depression is shown on the map (Pl. 26) by a broken line.

Between the Scioto and Olentangy, nearly two miles north of Powell, a well reached the rock 735 feet above sea level, or about 40 feet below the level of the Olentangy, which is on limestone and has here carved a deep rock gorge. This rock surface is also about 60 feet below the limestone floor of the adjacent Scioto. At Powell, the wells reached the rock at 800 feet above sea level. Streams east of the well reach it at 850 feet. Its surface seems to descend westward as if on the slope of a valley, hence the broken line indicating the probable course of a valley is drawn west of Powell. North and west of Elmwood (Linworth on the Hocking Valley railroad) the rock is very near the present surface, and 815 to 890 feet above sea level, even close to the Scioto; hence it would seem that no buried valley exists between Elmwood and the Scioto. At Elmwood, the rock surface is known to be only 700 feet above sea level and lower than the Olentangy River in the channel between Elmwood and Worthington. Hence, the broken line is made to cross the course of the Olentangy and pass near points eastward where the rock surface is known to be less than 750 feet.

Another line of low levels can be traced from northwest of Westerville, southeastward through that town, and back to the west side of Alum Creek, thence southward to join the line just traced, a mile or so south of Minerva Park; whence the course of the combined channels starts south-southeast by south and is lost. The channel leading westward from beyond Gahanna (Fig. 17) may well be supposed to unite with this one somewhere west of Gahanna. A group of deep wells west of Clintonville and the Olentangy found the rock surface at 760 and 695 feet above sea level and descending southward. Since no well was found in the rock southeast of this point toward the center of the city, and since the State House well found the rock at 637 feet above sea level, the broken line is drawn to indicate a drainage line leading southeast throughout the city. This line and those left farther northeast (Pl. 26) seem to be headed toward the supposed "Newark River"[1] valley, which may easily enter the area from the east between Reynoldsburg and Canal Winchester where the rock surface is known to be low. But so many records of the rock surface along the western side of the area were obtained, with none low enough by 100 to 150 feet to permit the drainage from such a valley or even the valley at the State House to escape, that it is believed that no considerable valley leaves the area westward. Since the rock seems to be generally out of reach by present wells through the central part of the southern half of the area, and to lie very low where found, it is believed that the exit for the preglacial and probably interglacial waters was southwestward. Where they went from there is not a part of the problem of this bulletin, but westward connections have been suggested by Dr. J. A. Bownocker[2] and W. G. Tight,[3] which seem entirely satisfactory so far as our local evidence is concerned.

Further evidence confirming this interpretation of the course of the old "Newark River" valley is contributed by two well records found beyond the boundaries of the area. The first well is three and one-half to four miles south by southeast from Pickerington, not more than one and one-half miles from the eastern side of the area and directly in line with the valley as suggested. The well is 232 feet deep and did not reach rock. This puts the rock floor here at less than 600 feet above sea level. The second well is one mile southeast of Ashville, about three miles beyond the southern boundary of the area and east of the Norfolk & Western railway. It is 212 feet deep and ended in fine sand without striking rock. This places the rock surface at less than 500 feet above sea level here. The so-called Newark Valley belongs genetically with the long,

[1] Read, M. C., Geol. Survey Ohio, vol. 3, p. 348. Tight, W. G., Bull. Sci. Lab. Denison Univ., vol. 8, pt. 2, pp. 47-59; also vols. 9 and 11. Tight, W. G., Prof. Paper U. S. Geol. Survey, No. 13, pp. 19, 23.

[2] Bownocker, J. A., Am. Geol., vol. 23, pp. 178-182. Ohio Acad. Sci., Sp. Paper No. 3.

[3] Tight, W. G., Bull. Sci. Lab. Denison Univ., vol. 8, pt. 2.

gentle, mature slopes discussed on pages 246 and 251, and not with the steeper slopes of interglacial valleys. A comparison with the rock slopes and the abandoned "Newark Valley" between Hanover and Trinway will make this fact clear.

While two or three main buried lines of drainage are suggested above, it is not asserted that these were all used at the same time, nor when any of them were used. Nor is it asserted that these are all the drainage lines now buried. Previous pages of this report mention others, and in the area there are at least thirty known buried valleys. There may be others as large as some of these, but evidence is not sufficient to show even their probable courses. In tracing these lines, only borings are used which have gravel or sand at the bottom or on the rock if they enter it, from a belief that such sections are more liable to represent old valleys.

Present Scioto and Olentangy Valleys Postglacial.

Resuming the record of these rivers where it was dropped (pp. 276-7), it will be shown that their valleys are largely postglacial, even though they intersect earlier valleys occasionally. The Scioto from the city south does not touch rock, although its bed is lower than known rock on either side (Pl. 26), hence it must lie in a former lowland area. This may be considered a valley, at least from Columbus southward to its intersection with the "Newark River" valley, probably near the southern border of the area. The present valley through this portion is all in drift, hence must be recorded as postglacial in a filled earlier valley.

North of Columbus, between the streams, there are several places whose rock floors are below the present channels, and yet the latter are on rock, and, for the most part, in rock gorges. It hardly seems possible that these present valleys are old ones re-excavated, when there occur so many depressions below their levels; and this possibility seems still more remote, since we can in places connect up the depressions as a system of valleys lying crosswise some of these present valleys, but at lower levels than they at the intersections.

Further evidence supporting the supposition that these streams have made their own valleys, since the Wisconsin stage is found in the rock terraces. As shown on another page, (pp. 279-80) the terraces in the limestone along the streams occur at all levels from that of the present stream up to the level of the surface of the rock below the drift; they systematically descend down stream faster than the present channel descends, and the upper ones have the steeper slopes down stream. Hardly could a stream get into an earlier valley, and clear it out, and find the features so thoroughly in accord with itself. In addition, if the valley with its terraces was here before the glacier made its last visit, the terraces should be ice trimmed, smoothed or striated. Not a

terrace has presented a striated surface to view, except a high one (820 to 830 feet) near its bluff side about opposite Hayden's Run.

Quarrymen were recently stripping off the mantle from the rock bluffs west of the Scioto about opposite Powell at an altitude of 80 to 100 feet above the river and 860 to 880 feet above sea level. The rock revealed was stream worn, but had no glacial markings of any sort. The terrace on the opposite side is about the same height.

The broad rock terrace between Slate Run and Fishinger's Bridge descends eastward, away from the stream as well as southward, and has a large sinkhole in it. Borings and wells east of it show the rock surface there to be lower than the terrace top, and the wells cited above, still further east, show the rock surface to be even below stream level. It seems here that the river barely missed getting into an old valley. After cutting down to this terrace which must have been a pre-Wisconsin rock surface, and stripping off the drift, then trimming the terrace a little, it swung off westward and made its gorge on that side, instead of sliding on down toward the east where the rock surface is so much lower. The possibilities suggested and the discordant slope of the terrace show what one might expect to find, were the present stream usually encountering a buried valley. The accordance everywhere else between stream and valley argues for the postglacial origin of the valley.

Again, neither the Scioto nor the Olentangy valley have led the ice forward resulting in a protuberance of the moraine. If there had been large valleys here preglacially, the ice should have pushed forward into them and should have built a protuberant moraine at such places. None of the present valleys has such a scallop on the moraine, nor could the buried valleys noted have been very broad, for they have not modified the ice-front either.

Forecast.

If one fully grasps the idea of development of physiographic features and succession of physiographic events, resulting in the evolution of present out of past topography, it is but an easy step to the conception of a future for the present topography. We have come upon the stage when the features of the present cycle are yet in youth. Their history is but begun. While they have had a past of considerable length, they also have a future; and, if uninterrupted, the future will be vastly longer than the past. Our acquaintance with this region may be compared to one's meeting a child for a day or two and hearing the sketch of his life down to date. Such an acquaintance with him might give one a glimpse of what he may become—a basis for a forecast of his future, provided, of course, that one had seen many examples of boys grown to men or knew the principles involved in such growth.

This region being in youth and under the influence of streams in a moist climate may be expected to continue to develop into maturity and pass into old age normally, if the conditions do not change. Climatic variation, a return of glaciers, or the incoming of arid conditions; or elevation, or depression of the lands; all of which have happened to the region, may interrupt the normal processes; but the forecast may ignore them at present and try to sketch what may come with a continuance of present conditions.

A few stream adjustments may be anticipated, but in a level region of such simple structure but few need be expected. It seems reasonable to predict a change some day between Alum and Big Walnut creeks south of Blendon. The former has been recently undercutting on its eastern side; the latter has a large loop or curve westward which may be still farther developed and pushed westward. Since but about three-fourths of a mile of territory now remains between the streams, and since Alum Creek valley is already 20 to 25 feet deeper than Big Walnut on the opposite side of the interstream area, one may expect Big Walnut some day to break through and enter Alum Creek, abandoning its own channel from this point down.

Another place where a change may some day occur is between the Scioto and Big Walnut at Shadeville. The streams are now not more than a mile apart, and modified drift constitutes the only barrier between them. The Scioto flood plain is about twenty feet lower than that of Big Walnut, hence, when the barrier is planed off, the new junction will at once become effective.

A third similar place is in connection with two small streams a little over a mile north of Reynoldsburg. Both are undercutting on their adjacent sides, and less than one-fourth mile remains between them. This adjustment may precede both of the others, because no rock seems to exist between them as high as present stream levels.

These predicted changes are somewhat phenomenal and the ordinary, gradual, every-day, developmental changes are really much more significant; and attention may now be turned seriously to them.

Streams will continue to widen and deepen their valleys, thus reducing both the steepness of the grade, and also the steepness of the valley walls. With wider valleys will come wider flood plains, a few more terraces, more meanders in the streams and larger but flatter alluvial fans on the flood plains. Laterals will multiply, and branches on the laterals will develop to the second, third and fourth orders at least, until by headward erosion the little tributaries will come to drain all the interstream areas. Waterfalls and rapids will be made to retreat upstream, until the layers that make them are intercepted by the bed of the stream which of course is higher up stream than near the mouth. Flood plains will come into the tributary valleys and into their branches. The upland will become more and more dissected; the interstream areas

smaller and more and more serrate-margined; the divides sharper and more easily found; all upland lakes and swamps will be drained and no level tracts of land will remain, but all will be on slopes. Finally, flood plains on the stream level will be the largest plains and will have the gentlest slopes; valley walls will become very gentle and will stand far apart and be thickly mantled with waste; and the remnants of the upland plain (the till plain of today) will be restricted to broad, low, uneven-topped ridges, or rows of isolated hills, as far from the streams as possible. Streams will no longer be subject to destructive floods and all change will be exceedingly slow.

PART III.

ECONOMIC GEOLOGY.

By J. A. BOWNOCKER.

CHAPTER VI.

The economic materials of a Geological nature within the area included in this bulletin are of the commonplace variety. Of the fuels, coal, oil or gas, there are none, and the same is true of the metals. However, the materials are of decided value and bid fair to enhance with increasing population and the extension of business. The most valuable asset by far is the fertile soil. Second in importance is the limestone which underlies the drift in the western half of the area and which is now worked on a great scale. The other materials are of lesser value. The list and the order of their review in this chapter is as follows:

1. Stone.
2. Clay.
3. Sand and gravel.
4. Search for oil and gas.
5. Underground waters.
6. Soils.
7. Agriculture.

STONE.

As already stated in Chapter I. the western part of the territory discussed in this bulletin is underlain with the Monroe limestone, or as it was formerly called the Lower Helderberg or Waterlime. Thus far this stone has not been used as a building stone or for other purposes. Farther east the Columbus and Delaware limestones outcrop, especially along the Scioto River. As is shown in the following paragraphs, one of these, the Columbus, is extensively quarried for a variety of purposes. Still farther east the Berea grit is found at the surface or just below the drift, and while it has a little value it is as nothing compared to the same formation in northeastern Ohio, forming, as it there does, one of the finest building stones in this country.

The Columbus Limestone.

Characteristics.—Economically this is one of the important limestones of the state, being used for flux, buildings, ballast, roads, walks, concrete, lime, fertilizer and in the manufacture of glass and soda ash. Quarrying of the stone for buildings and for lime began in the early

days of Columbus, but the work did not become extensive until about fifteen years ago. Now it is the basis of one of the large industries of central Ohio, though the prime use of the stone is no longer the same as in years gone by.

The rock is fairly even bedded, but the layers vary much in thickness. (Plate XXXV.) Thus at Marble Cliff the range is from less than one foot to more than six feet, the thickest layers being below. The rock is strong, meeting in this respect the severest demands of the architect or engineer. The surface of the layers varies somewhat, giving rise to such names as rough rock, hackletooth, smooth rock, etc. Occasionally it is quite crystalline and takes a fair polish. In fact some of the beds were once thought to be marble, hence the name Marble Cliff. The color ranges from buff to blue, the former predominating. On exposure the shade may darken and often becomes mottled.

The composition of the stone varies from place to place and from layer to layer, and sometimes the changes are notable. Thus the "bone-bed" is high in phosphate of lime, one analysis showing over 16%.[1] Probably the basal part of the same layer would show less than one-tenth of one per cent. Silica is low, ranging commonly from 1 to 4%, both extremes being unusual. The iron and alumina usually comprise less than 1% of the rock.

Greater variation exists in the carbonate of lime and carbonate of magnesia, and as one increases the other decreases. In other words when one is high the other is low. The carbonate of lime is highest near the top and decreases irregularly with the depth. It may exceed 96% and fall to about 80%.

The carbonate of magnesia is lowest near the top, where it may be less than 1%, and highest near the base where it may exceed 16%. These relations are well shown in the two following analyses, the first of the "Gray Rock" near the top of the formation and the second of the "Six-foot Six" near the base:

Composition of "Gray-Rock."

	Per cent.
Carbonate of lime	96.51
Carbonate of magnesia	1.43
Silica	1.10
Iron and alumina	.70
Phosphorus	.04

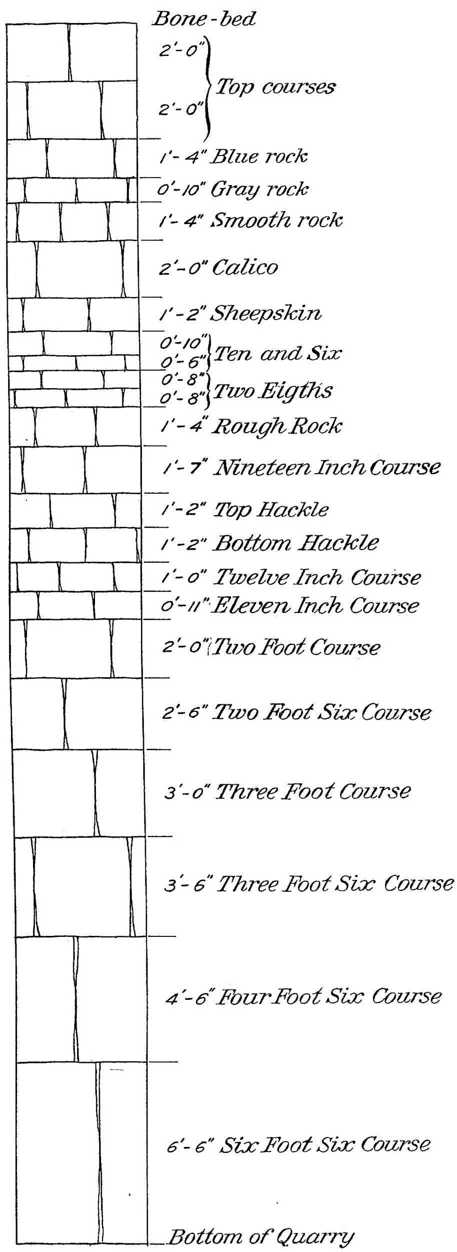
Composition of "Six-Foot Six."

	Per cent.
Carbonate of lime	80.900
Carbonate of magnesia	16.070
Silica	2.000
Iron and alumina	1.100
Phosphorus	.016

Building Stone.—The formation has had an extensive use for

[1] Orton, Edward, Geol. Survey of Ohio, vol. 3, p. 611.

PLATE XXXV.



Section of Columbus limestone at Marble Cliff.

buildings, the best known structures made from it being the State House and Judiciary Building. The former was erected more than a half century ago, and furnishes a good illustration of how the formation withstands the trying Ohio climate. The stone for this building was secured from the quarry just north of the State Hospital, the lower beds supplying the heavy courses for the walls and columns, and the higher beds, especially the "Sheepskin," for the steps. The Judiciary building, erected about fourteen years ago, is made from stone from the old Taylor and Bell quarry, just across the Scioto from Marble Cliff. Examination of the walls of the State House shows that the stone does not weather uniformly, the result being a rough surface. However, the formation is at its best in these massive structures.

The stone has been but little used in walls of residences owing to its unattractive appearance, but it has had an extensive market for foundations and door and window sills and caps. It is used in these ways in a large proportion of the residences and other structures of Columbus, its only rival being the Berea grit. The latter may be easily recognized by its more even layers and the limestone by its rougher surface. Further the limestone develops a slightly mottled surface on weathering, and the sandstone may have a light yellow or even yellow brown tint. A little practice makes it easy to distinguish between the two.

Practically the whole of the Columbus limestone may be used for building purposes. Naturally the thickest layers are best suited for massive structures while the thinner beds serve for caps, sills and steps in ordinary structures. The layers do not vary greatly in a physical way, so that one works about as easily as another. The stone does not carve well. In former years it had a market for curbings and flaggings, but this is now supplied by sandstone and concrete. It has been used also for pavements.

All in all the formation cannot be classed as a first rate building stone, except perhaps for massive structures, its appearance being unattractive, and it is gradually being discarded except for foundations.

In Making Pig Iron.—The great demand for the stone is for this purpose. It unites with the silica of the iron ore and the ash of the coke, forming a fusible slag which is drawn from the furnace at regular periods. For use in making pig iron the limestone must be low in phosphorus because that element makes the iron brittle. Silica and sulphur also should be low. Not all of the beds can be used for this purpose, and at present the upper limit is the "Gray Rock." All below this layer is available, though some beds are better adapted than others. The demand for the Columbus limestone for making pig iron is very large and bids fair to continue so many years. At present the market extends as far as Wheeling, Cleveland, Cincinnati and Ironton.

Other Uses.—The stone has a small market at Barberton where it is used in making soda ash. When ground to a powder it is a constituent in glass manufacture. A smaller use is for fertilizing, serving to neutralize the excess of acids in certain soils and to supply lime in others. Pieces that cannot be used for other purposes are crushed for ballast on railroads, for concrete and for making roads and walks.

Formerly it was extensively burned for lime and the last of the old kilns at Marble Cliff has recently been torn down. In fact it is still occasionally burned in a very small way at Dublin. The stone makes a good lime and the decline of the industry is due in part to the sharp competition of other localities, but more largely to the fact that the stone can be used with more profit in other lines.

The Delaware Limestone.

While in other parts of the State this stone may be classed as a limestone, in the territory near Columbus it is represented by shales. These have to be removed to reach the Columbus limestone, and being unsuitable for other purposes are crushed and sold for ballast, road-making, walks and concrete. The Pennsylvania Railroad uses it for ballast as far east as Pittsburgh and west to the Indiana line.

The Berea Grit.

As the Areal map shows, the Berea grit outcrops across the eastern part of the territory, along a north and south belt. The formation is drift covered, but exposures are found along streams. It is of very little importance and is nowhere worked regularly. At the village Harlem the stone has been quarried in recent years for road making. It is crushed and covered with a layer of limestone, but is soft and crumbly and does not make a good road, even when covered with better material.

A few pieces of stone are occasionally taken out for building purposes along Rocky Fork near Gahanna, and the presence of an old pit at that place suggests that it was formerly worked in a little more pretentious way.

The Cuyahoga Formation.

This formation, which underlies the eastern part of the area, contains a few layers of sandstone. It is of very little importance, but is worked with some regularity in two quarries. One of these is at Lithopolis where the stone is said to have been quarried in a small way forty years. The principal stratum measures nearly four feet in thickness and a little higher is one of two feet. The remainder of the stone in the

quarry is of little or no value. The two layers are worked in large blocks, hauled on wagons to Canal Winchester and then shipped to Columbus where they are sawed to desired sizes and used in door sills and window caps. The available supply, however, has been largely worked out. It has a light color and is of good quality.

The other quarry is near Reynoldsburg and has been worked many years. The quality is similar to that at Lithopolis, and the supply is larger. The desirable layers range from 3 to 48 inches in thickness, and are separated by beds of shales that vary ordinarily from one to five inches. The total thickness of the workable stone and included shales is about 18 feet, but this may vary from place to place. Nearly the whole output is sawed into pieces of suitable sizes and hauled to Columbus. It is used for flagging and for purposes similar to that from Lithopolis. The stone is reported to have been used for culverts and bridges in building the National Road.

Years ago the stone was quarried along the creek just east of Black Lick station. It generally occurs in thin even beds, but sometimes this character is wanting. Often the grains of sand are not strongly cemented, and the rather large proportion of clay present absorbs water which may cause cracking on freezing. The layers vary much in value, the best being of fair grade and the poorer worthless. They are often separated by beds of shale which increase the expense of quarrying. The stone forms the walls of the Institution for the Blind at Columbus and has been used in many other structures.

CLAYS.

The term clay is rather loosely used. Popularly it refers to the fine material found nearly everywhere on the earth's surface. Since, however, shales are in most cases simply mud that was deposited under water and then more or less solidified, they too are often classed with clays. Strictly speaking clays consist of kaolin mixed with various substances such as silica, silicates, carbonates, oxides and hydrates. Kaolin is formed in the main by the decay of feldspar which is a common mineral in granite and many other igneous rocks. Pure kaolin is not often found in large quantities, but when mixed with the various materials just referred to, it almost covers the earth's surface.

The nature and quantity of materials mixed with kaolin have an important effect on the clay. Thus iron colors it, and when the clay is burned gives a characteristic red which grows darker and may become black if the heat is sufficiently high. If the iron present is very small the clay may burn buff, and the same color results when lime is abundant, since it serves as a bleaching agent. The iron, magnesia, potash and lime (known as fluxes) lower the melting point of clay. The best fire clay is a variety having but little of these substances and so fuses

only at a very high temperature. This variety is commonly found underlying coal seams for the reason that the vegetation of which the coal was made removed the iron, magnesia, lime and potash contained in the clay, thus changing it to fire clay. Clays high in kaolin and low in other minerals are used in the manufacture of the finer wares such as pottery, while the more common varieties serve for bricks, tile and sewer-pipe. The clays found in the territory included in this bulletin are all of low grade, and occur at three horizons as follows:

Ohio Shales.—These extend across the middle of the territory from north to south and are inexhaustible in quantity. Fine exposures may be seen at many places, notably along the Olentangy River and many of the small tributaries to it.

While these shales may be used for the more common products such as bricks, drain-tile and sewer-pipe, they are not well adapted for any. The composition may vary rapidly in vertical section and areally, making the product hard to control in the kiln and the result uncertain.

Frequently considerable carbon is present, the residue of marine plants of the Devonian sea. The combustion of this, while the clay is burning, may, under certain conditions, produce too high a temperature, fusing the clay, and of course warping the tile or brick. Sulphur also is present in varying quantity, and sometimes concretions of pyrites (sulphide of iron) are common. The effect of sulphur depends quite largely on its condition, that is, whether it is free or combined with other elements. Often it appears on the surface of the finished product as a white coating that is unsightly and of course injures the sale.

Calcium carbonate is another substance that is nearly always if not always present. In certain layers this may comprise a large part of the mass while in others it may be very small or possibly wanting. The effects of this are various, depending in part on the proportion and on the other substances present. It may promote fluxing, and if abundant acts as a bleaching agent, so that the product has a buff color.

The iron present is in the form of carbonate, sulphide and oxide, and the proportion of these varies notably in different parts of the shales. Iron promotes fusion and influences the color. The latter, however, is not dependent entirely on the amount of iron, but also on the form in which it exists, the other substances present, the degree of heat, and the physical state of the clay.

These shales were formerly used in a large way at North Columbus in the manufacture of sewer pipe. The plant was established about 1869 and soon became a large producer. The market extended from Maine to Mexico, and it is said that sewer pipe from this factory was laid in every state east of the Mississippi River. The shales were ground and moistened and then moulded into the desired shapes and

A.—Brick yard at Taylors.

B.—Artesian well near Harrisburg.

sizes. The material shrank greatly on drying and burning, making it difficult to keep the larger sizes in shape. Salt and manganese oxide were thrown in the kiln, the former for a glaze and the latter to give the product a dark color. In 1900 the plant was sold to the American Sewer Pipe Company which operated it a short time and then for business reasons closed it. Later the plant was leased to a brick company which ran it for a short period.

The plant of the Fish Pressed Brick Company was located at the intersection of East Fifth Avenue and the Big Four tracks. For many years its product found a large market both at home and at more distant places. Financial difficulties finally closed the works. Products made from these shales burn to a light red, but a higher temperature darkens the shade somewhat.

Bedford Shales.—These outcrop as a rather narrow strip along the eastern border of the Ohio shales. Exposures are much less common, but the dark red color makes them conspicuous. At present these shales are used for bricks or drain-tile at two places, Canal Winchester and Taylors. At the former the use is so small as to be hardly worth mentioning, but the two plants at Taylors are more important. The bricks are used in buildings, sewers and to a small extent for paving. Only the more common varieties are made.

Glacial Drift.—This covers practically the whole area and is often suitable for common bricks and drain-tile. The latter is made at many places, in truth "too numerous to mention." Brick kilns also are found. Probably the largest plant of this sort is at Groveport where a clay from the valley of Big Walnut Creek is used. This gives a color that ranges from light red to black and the product finds a market as far distant as New York. A plant at Westerville has been in continuous operation since 1876, making at present building bricks and blocks and drain-tile. A clay from the valley of Alum Creek is used.

From what has been stated it is clear that the territory considered in this bulletin contains a vast quantity of clay that may serve in the manufacture of the most common products, though the output at present is small.

SAND AND GRAVEL.

Large deposits of these are not widely distributed in the vicinity of Columbus. Especially is this true of the northern half of the territory. Farther south sand and gravel are more abundant. They occur in the valleys and channels of streams, and also outside of them. All of these deposits are due quite largely to glacial and fluvio glacial action. In the valleys the glacial materials have been worked over by running water, but outside they usually lie as the glacier or glacial waters left them. Generally the sands and gravels are distinctly stratified.

A large deposit of gravel is found on the east side of Walnut Creek, where the Columbus Buckeye Lake and Newark traction line crosses, and has been extensively used in road building by that company. Baker's Hill, south of Columbus, is essentially a mass of sand and gravel. Much of it has been used by the Scioto Valley traction company in making the fill near Obetz Junction. Other hills of these materials are found on the Hartman farm south of Columbus.

Within the past few years a unique industry has developed at Columbus. This consists of dredging the channel of the Scioto for sand and gravel. Two styles of dredges are used. One lifts the materials in buckets while the other sucks it up. Once on board the dredge, the material is screened, the finer forming sand and the coarser gravel. Boulders secured in the process are crushed and mixed with the gravel.

It might be expected that the sand and gravel removed in this way from the bed of the river would be replaced promptly by high water. This is quite true, but the substance is mud, showing that the Scioto transports only fine material in this locality. Above the city this river flows over bed-rock. Possibly large beds of sand and gravel may be found in the channel below the city.

The valley of the Scioto from Columbus south contains in places important deposits of gravel. These are at present worked at one or more points on the west side of Columbus. Probably many residences in that part of the city stand on beds of this material.

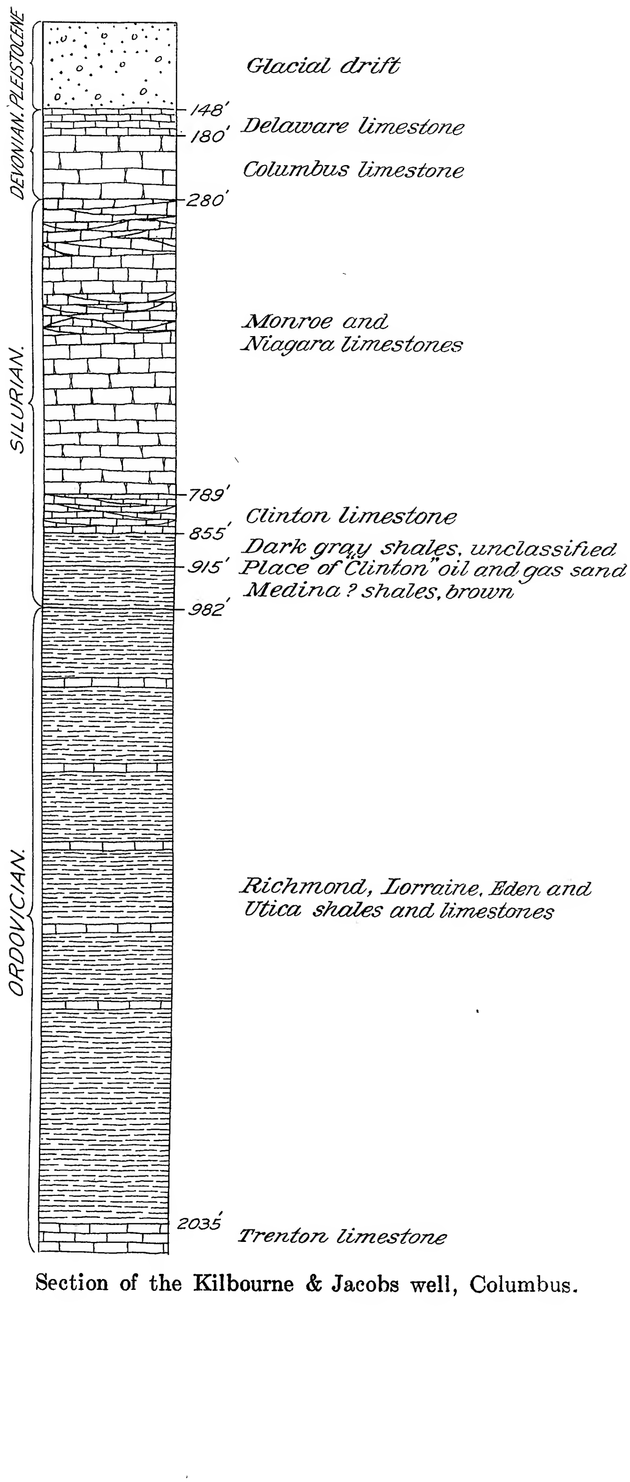
The uses of sand and gravel are well known. Probably the most extensive one of gravel is road building, but it is used also in making walks, in concrete and in certain kinds of roofing when tar is used and protected with a light cover of gravel. Sand has a large demand for making plaster and in cement work.

Where gravel is lacking the farmers are much handicapped in building good roads. Northwest of the city, crushed limestone from the quarries along the Scioto is used, but to the northeast this is lacking. As might be expected, the roads there are poor, but within the past few years the farmers have begun building pikes with crushed stone. This is commonly sandstone in part, obtained in nearby quarries and is covered with limestone from the Scioto Valley.

SEARCH FOR OIL AND GAS.

The discovery of natural gas in the Trenton limestone at Findlay in 1884 and of oil a year later encouraged drilling in many parts of the State. Columbus citizens were quick to see the benefits that would result from the discovery of oil or gas, and in 1886 drilled a test well in the valley of the Olentangy near Buttles Avenue. The stratum sought was the Trenton limestone which was yielding such surprising results in Northwestern Ohio. This was reached at a depth of 1,915 feet and drilling ceased at 2,020. Not a trace of either fuel was found.

PLATE XXXVII.



Section of the Kilbourne & Jacobs well, Columbus.

Not satisfied with this test, the Kilbourne & Jacobs Company drilled a well on their grounds in 1891, the object being a supply of natural gas for their shops. The Trenton was reached at a depth of about 2,027 feet, but contained neither oil nor gas. A record of this well, showing the formations drilled through and their thickness, may be seen on Plate XXXVII.

While these wells are the only ones drilled in Columbus for oil or gas, neither was the pioneer. Many years ago (1857-1860) a well was sunk on the State House grounds to secure an adequate supply of pure water for the Capitol. The drill did not come to rest until it had reached a depth of 2,775 feet. This well too was a failure, for at a depth of 180 feet sulphur water was found, and at 675 feet a brine.[1] The Trenton was shown to be 475 feet thick and below this was found 316 feet of white sand-rock.

The deepest well drilled in the vicinity of Columbus was on the Hartman farm south of the city. It reached the unusual depth of more than 3,100 feet, but like the rest was a failure.

About 1896 a determined effort was made to secure oil or gas in the valley of Big Darby near Harrisburg. Three wells were sunk, each reaching a depth reported at about 1,680 feet. Like most wells drilled at that time, the objective rock was the Trenton which should be found at a depth approximating 1,825 feet. At depths reported from 388 to 400 feet a large supply of fresh water was secured which still flows to the surface. (Page 314.)

Some years ago a well was drilled on the Rohr farm in Madison Township near the junction of Alum and Big Walnut creeks. The Trenton limestone was struck at 2,140 feet, but work continued until a depth of 2,675 had been reached. Neither oil nor gas was secured. A test was made in the valley of Alum Creek about three miles northeast of Linden. The Trenton was reported at 2,170 feet and the drill was kept at work until the formation had been penetrated to a depth of 159 feet. The failure of the well was complete. About the same time a well was drilled on the William Morrison farm, one mile east of Blacklick. It reached a depth of 2,153 feet ending in the red shales called Medina. The "Clinton" sandstone was absent, its place being occupied by shales. Neither oil nor gas was found.

Early in 1911 a well was completed in the extreme southwest corner of Mifflin Township near the northeastern corner of Columbus. The top of the Devonian limestone was found at 274 feet and the base of the Clinton limestone at 853. The Trenton was struck at 2,110 feet and the drill was kept at work until a total depth of 2,630 feet was reached, but neither oil nor gas was found.

In 1909 a well was sunk to the horizon of the "Clinton" sand-

[1] Orton, Edward, Geol. Surv. of Ohio, vol. 6, pp. 107, 108; also, vol. 1, pp. 113, 114.

stone in the valley of Little Walnut Creek near Canal Winchester, but the desired rock was absent and the well was a total failure. About the same time a test was made on the Oyler farm a short distance southwest of Lithopolis, the result being similar to that near Canal Winchester.

Other wells were drilled many years ago in search of oil and gas, but the records have been lost. Among the places where tests were made may be mentioned Canal Winchester, Westerville and Sunbury. Probably all these reached the Trenton limestone. The numerous wells drilled on the territory included in this bulletin seem to demonstrate that oil or gas in commercial quantity is wanting.

It may be worth mentioning that the rock from which gas in great quantity is secured in central Ohio is absent in the Columbus territory, its place being taken by shales. The gas is derived from a bed of light colored sandstone about 25 feet in thickness. The position of this rock varies from about 105 to 200 feet below the Clinton limestone, and it is covered and underlain with shales. It is commonly called the Clinton sand, but its age has not been definitely determined. The location of the deep wells in the vicinity of Columbus is shown on the map. (Plate XXXVIII.)

The absence of the Clinton sandstone explains why oil and gas are not found in that formation, but the reason for failure in the Trenton is unknown. It may be due to smallness of porosity or to the absence of folds or anticlines which many think are essential to these fuels in large quantity. Possibly the failure may be a result of unsuitable conditions for preserving the life of the Trenton or to the formation of oil or gas from it.

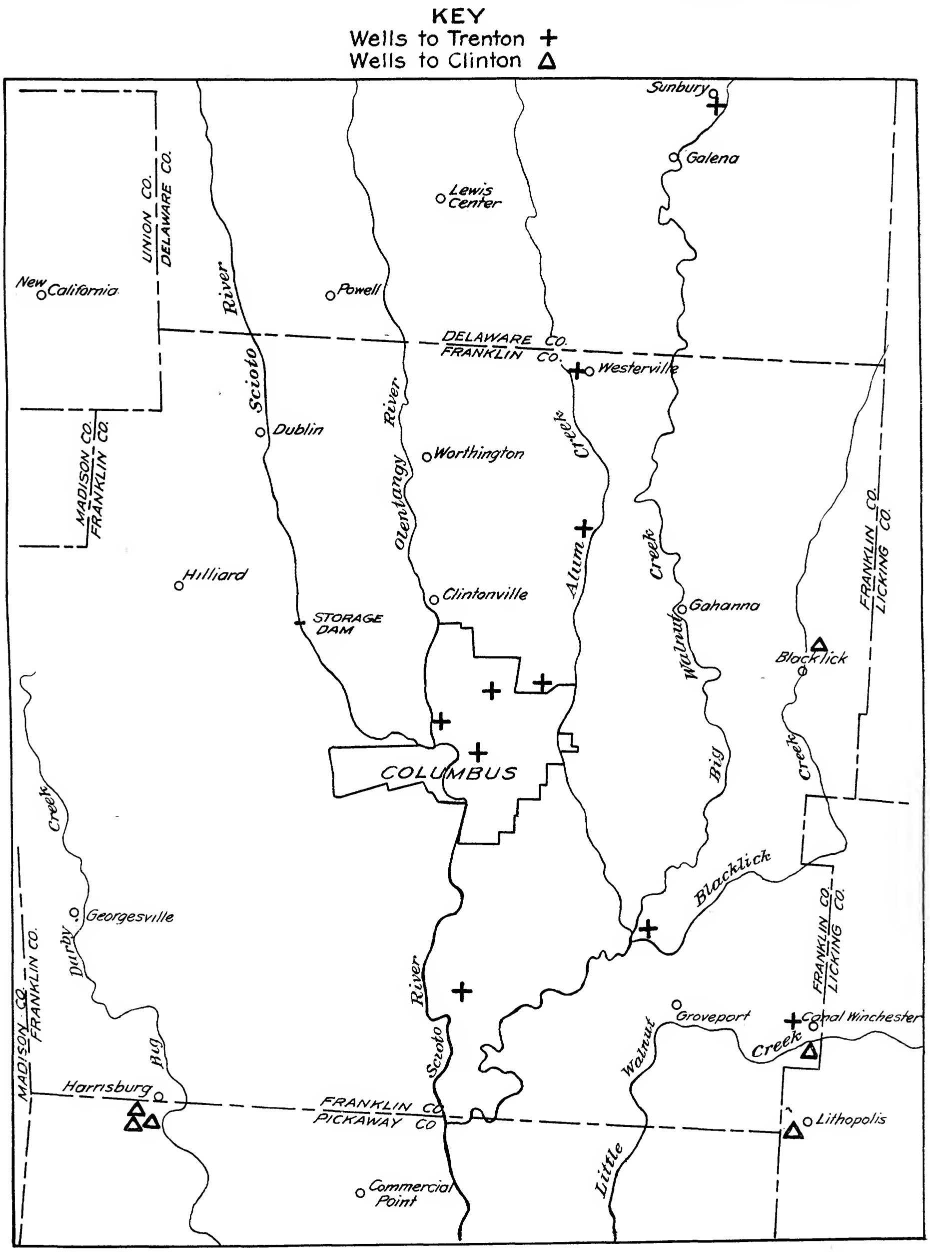
UNDERGROUND WATERS.

These depend chiefly on the precipitation in the form of rain and snow, nature and thickness of the surface material or mantle rock, and the porosity and structure of the bed-rock.

The importance of precipitation is self-evident and so will not be discussed here. The quantity of water that may be stored in the mantle rock depends on its thickness and its porosity. When the mantle rock is of fine material like clay, the porosity is small and little water can be stored. In fact such material is sometimes quite impervious; but when it consists of coarser materials and especially when it contains much sand or gravel the porosity is large and the quantity of water that may be stored is in proportion. It is apparent therefore that the amount of water that may be found in the mantle rock varies from place to place. Especially is this true in drift covered areas where the texture changes rapidly.

Much the same may be said of the bed-rock. It may be porous and capable of storing a large amount of water or it may be fine and

PLATE XXXVIII.



Deep wells drilled on the Columbus quadrangle.

quite impervious. Cracks, joints and bedding planes in the bed-rock are another factor, for they too may serve to store the water. Our territory well serves to illustrate these points. Thus the limestones which underlie the western half of the area are porous and much broken by cracks and joints. Often these have been enlarged near the surface by solution. Further the bedding planes are well marked, making the formation as a whole capable of storing a large supply.

The shales, on the contrary, are fine grained and quite impervious. They are cut by many cracks and joints, but the faces of these fit closely. The bedding planes are innumerable, but so compact are the layers that there is little or no room for water. Manifestly large supplies cannot usually be secured from such rocks.

Underground water always contains mineral matter in solution. The nature and quantity of this is determined largely by the composition and solubility of the rock through which the water has flowed and in which it is stored. Thus on those tracts underlain with limestone the water contains much of that substance in solution and is "hard." This applies whether the well penetrates bed-rock or stops in the mantle rock, for the nature of the latter is commonly quite largely determined by the former. On the shale covered areas the water contains less mineral matter because the underlying rocks are less soluble. However, the glaciers left some limestone in the drift of those areas, and that of course modifies the water.

Iron is another common constituent of water. Usually it is in the form of ferrous carbonate ($FeCO_3$) and is not visible when the water first reaches the surface. The atmosphere rapidly oxidizes the iron to limonite ($2Fe_2O_3$, $3H_2O$), an insoluble body of yellow brown color which settles to the bottom. In this form it is frequently seen along the channels of streams and on the beds of ponds. Sometimes the iron accumulates in this way in sufficient quantity to warrant mining and is known as bog ore, though no such deposits are found on the Columbus area. However, iron is commonly present in the springs and wells of this locality.

Occasionally water from springs and wells has the disagreeable odor of hydrogen sulphide. The source of this gas in such cases is not quite clear, but it probably results from the action of water on iron pyrites (FeS_2). The Ohio shales contain much of this mineral and it is on such areas that water with this odor is usually found. The best known springs of this kind in Ohio are at Delaware.

Wells.—Except in a few small areas, mostly along streams, the mantle rock has a depth adequate to hold a large volume of water, but often it is too compact. Wells in such places may give an inadequate supply and fail in time of drouth. Farmers meet the difficulty by digging deeper. The depth at which a satisfactory supply is found varies

greatly even where the surface is level or gently rolling. This results from the water bearing horizon rising or falling independently of the surface, as shown in Figure 22. Wells in the vicinity of Columbus commonly range from 15 to 50 feet in depth.

Quite often wells are drilled, the work being done by machines. Such wells are deeper and may penetrate the limestone where it lies immediately below the drift. They may exceed a hundred feet in depth

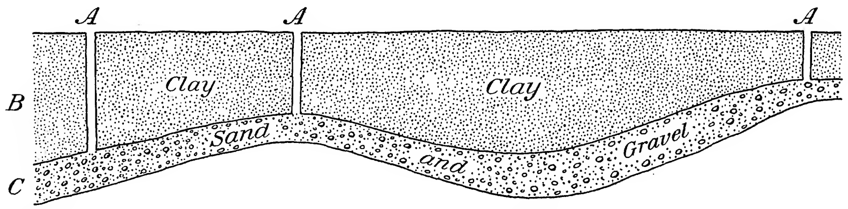


Fig. 22—Showing why the depth of wells varies on a flat surface. The letters A represent three wells. The bed of clay is fine grained and contains very little water, but the underlying bed of sand and gravel is porous and may be charged with water.

and usually give a large supply. Many wells of this kind exist in Columbus, supplying manufacturing plants or other industries requiring a large volume. Water obtained in this way is less likely to be contaminated with organic matter, but it is usually very "hard."

Artesian Wells.—A few artesian wells are found. Two fine ones may be seen just east of Harrisburg, one of them supplying the farm of the Columbus Hospital for the Feeble-minded. These wells were drilled for oil or gas (page 311), the supply of water being obtained at reported depths of from 388 to 400 feet. The artesian flow is due to the water bearing rocks rising to the west and being covered with an impervious layer of clay or shale. The water at depth is under "head" or pressure and flows to the surface wherever an opening is found. A precipitate of iron along the stream leading from the well indicates that the water contains some of that metal.

Near the corner of East 11th Avenue and Summit Street, Columbus, is another artesian area, but in the past few years so many wells have been drilled that the flow has weakened. The water was formerly found at a depth of a few feet and in several instances was encountered in digging cellars. Here the phenomenon seems to be restricted to the drift, but the general principle of "head" or pressure stated above holds.

Springs.—Springs are common, especially along the west side of the Scioto River where it cuts through the limestone, offering an outlet for the waters which have been stored in the rock. The Wyandot Spring, now submerged by the storage dam, is the best known of these. Tradition has it that Indians formerly camped in that locality on account of the water.

PLATE XXXIX.

The University spring.

The hills around Lithopolis have many springs, a few being large. The water-storing rock is mostly sandstone which is comparatively insoluble, and hence the water contains little mineral matter. One of the springs, "The Jefferson," is used in a commercial way; the water is bottled and shipped to Columbus where it is used for drinking purposes.

However, the most valuable spring on the area considered in this bulletin, is located on the grounds of the State University. A visit at almost any time, but preferably on a warm day, will show its popularity. Interesting too, it was a factor in determining the location of the University. After the generous offer of a large sum of money, made by Franklin County to secure the institution, had been accepted, various tracts were offered for sale to the trustees, and among them the Neil farm on which the University now stands. Naturally the trustees gave careful consideration to so important a question. After much discussion the situation was finally cleared by the remarks of a German-American member. "When at last he reached in his review the Neil farm, while extolling the character of the land as equal to any they had seen, he declared that 'dot sphring' settled the question for him." The trustees voted with the speaker, and so the University is by the spring.[1]

About twenty years ago a sewer was constructed along the south edge of the lake and hence near the spring. It was supposed that the water feeding the spring came from the higher land to the north and hence would not be intercepted. However, the water flowed into the sewer and the spring went dry. Later the sewer was torn out and rebuilt in such a manner that water could not flow through its wall, and in consequence was compelled to resume its old course. Since that time the spring has pursued an unsteady way. The flow has varied greatly and occasionally has ceased. Lowering the lake level a few inches will stop the flow of the spring at once. This indicates that the sand and gravel underlying the valley and the lower part of its slopes are charged with water and whenever the level of the lake falls, that in the slopes likewise drops and may fall below the outlet of the spring. In the latter event it, of course, ceases flowing. The drift outside of the valley to the north, east and south contains much sand and gravel which stores a large volume of water, and this flowing toward the valley maintains the supply that feeds the spring.

SOILS.

Sources.—In an unglaciated region the character of the soil depends on the underlying bed-rock, for the soil was formed from it. Along streams, however, the soil may have been transported some distance, and so may show marked differences from the bed-rock.

[1] Address by Dr. Edward Orton. Twenty-fifth anniversary of the establishment of the University. Published by the University.

In glaciated regions the soil is derived partly from the underlying rocks, but more largely from those a short distance in the direction from which the ice came, and to a much smaller extent from more distant places. Thus the soils in the area discussed in this bulletin, being glacial, have been formed largely from the limestones, shales and sandstones which underlie the area, but they contain materials from the counties to the north and to a much less extent from the territory north of the Great Lakes.

As has been shown in Chapter I, the bed-rocks in this vicinity form usually rather narrow strips that extend north and south. The glacier in this territory moved south, and hence the soil of any locality is much the same as if it had been formed from rocks just below, and had added to it materials from the comparatively distant north. In other words, where the bed-rock is a limestone, it is usually overlain with a limestone soil; and where it is a shale, it is covered with a shale soil. However, along or near the line of junction of the shales and limestones, the soils may contain materials derived from each.

Varieties.—The soils of this area consist of loams, that is, clays containing sand or gravel. Depending on the proportions of these the following varieties are recognized:

Soil.	Square miles.
Miami clay loam	767
Miami black clay loam	72
Miami loam	71
Miami gravelly loam	35

These form irregular patches so that when they are shown by different tints, the map has somewhat the appearance of "Joseph's Coat." These variations result from glacial deposition and the work of streams.[1]

As shown above, the Miami clay loam is by far the most abundant. In fact, it covers the entire area, except along streams and numerous but usually small patches on the uplands. Its value is not uniform, for it is dependent in large part on the bed-rock, as will be explained later.

The Miami black clay loam differs from the preceding variety chiefly in its color. Nearly always it is found on tracts a little lower than the surrounding land. Its color is due to an accumulation of vegetable matter which in part grew on it and in part was carried from the higher land, wind and water serving as the transporting agents. Such tracts are usually small and are most abundant in the southern half of the territory. When drained, they are more fertile than the surrounding Miami clay loam.

The Miami loam is of finer texture than the preceding varieties.

[1] For maps, see Bureau of Soils, U. S. Dept. of Agriculture, 1902 and 1905.

In other words, it contains more material like silt and clay. It is found in valleys and so forms narrow strips, the widest being along the Scioto south of Columbus. It is a deposit made by streams, and usually overlies a bed of gravel. The dark color is due to the presence of vegetable matter scattered through it. As a rule it is very fertile.

The Miami gravelly loam, as its name indicates, contains pebbles or gravel, but the percentage of this need not be large. Such areas are found along or near streams and sometimes form the second bottoms or terraces. They are largely the work of glacial waters, and are more extensive on the southern half of the territory.

Fertility.—The classification just given is based almost entirely on fineness of grain. Fertility, however, is not wholly dependent on the physical state. It is modified to no small extent by the chemical composition, which in turn depends (1) on the rock from which it was derived, and (2) on the organic matter present.

Considered from the standpoint of bulk, soils consist largely of clay and sand, but these alone would not support vegetation. In fact it can scarcely be regarded as settled just what is necessary to form a soil, but most authorities include lime, magnesia, iron, potash, sulphuric and phosphoric acids.

Soils formed from limestones are usually more fertile than those from shales or sandstones, because the rock and hence the soil is richer in the essentials to plant growth. Practically all limestones contain both lime and magnesia. The iron present may be in the form of the sulphide and this on decomposition may yield iron and sulphuric acid. Another common constituent, though usually in small quantity, is calcium phosphate and this supplies the phosphoric acid.

As a rule the limestone soils of Ohio are notably richer than those formed from sandstones and shales. This is best shown in those parts that were not glaciated, the farmer stating with pride that "my land is of limestone origin." It is also demonstrated by the glaciated parts of the State, for the western half which is underlain with limestones is much more fertile than the northeastern, which has a floor of shales and sandstones.

It is unnecessary, however, to go so far from home for illustrations of this kind. Thus a large part of the western half of the territory discussed in this bulletin has a limestone floor while the remaining portion is underlain with shales or sandstone. Usually a single trip will show the superiority of the soils in the former area. This is best shown by crops which require a strong soil, such as corn.

Eastward from the Scioto River the bed-rock is largely shales which have yielded a soil poorer in plant food. Besides it is fine grained and does not freely permit of atmospheric circulation or the escape of an excess of water, such as is present in springtime or after heavy rains.

In times of drouth the soil is hard. The best examples are found in the northeastern part of the territory.

The production of the soil in such places would be notably augmented by draining. This may be in the form of open trenches, or better of tiling or of both. Two farms, side by side, one well drained the other not, give very different results, especially during a wet season. Probably no one thing would so greatly increase the productiveness of such areas as draining. It is expensive, but the yield more than compensates.

In the southeastern quarter of the territory, that is from Columbus to Greencastle, the character of the soil has been modified more by the glacier than in the area referred to in the last paragraph. The soils contain more sand and gravel, and in places are of superior quality.

The valleys, as might be expected, are more fertile than the upland. Their soils contain more sand and gravel, and hence have better natural drainage and work more readily. In addition they appear to be richer in plant food, having a larger variety of minerals and also more organic matter. Much of these may have washed from the adjacent uplands. In fact this transfer is the principal reason for the general superiority of valley soils.

These soils are a valuable asset of the Columbus territory. The Scioto Valley south of the city has a maximum width of a mile, but north of the city it is much smaller. The valley of Big Darby in the vicinity of Harrisburg varies from one-half to three-quarters of a mile in cross section, but is much narrower to the north. The third important valley in the western half of the territory is that of the Olentangy, whose width usually ranges from a quarter to a half mile. The soils of these are of marked fertility and are especially well adapted for corn and alfalfa. Probably those parts near the city will be more largely used in the near future for gardening.

On the eastern half of the territory the valleys are smaller and on the average less fertile, the soils having been derived more largely from shales. The valley of Alum Creek varies from a quarter to a half mile in width and that of Big Walnut averages less, except below its junction with Alum and Blacklick Creeks, where it is wider and notably fertile. The valleys of Blacklick and Little Walnut are still narrower. That of the latter has a rich soil and yields large returns, especially from corn.

All the valleys in the territory covered by this bulletin are subject to overflow and the damage to farmers resulting therefrom is sometimes large. The control of these floods is attempted by levees, but the result has been only partially successful. Sometimes the waters leave a deposit of material that adds to the fertility. At other times sand and gravel are deposited. Occasionally the waters erode and then may sweep away the soil.

As a summary it may be stated that the soils are fertile but vary

from place to place; that those overlying the limestones are generally richer than those over shales, and that those in the southern half of the territory are better than those in the northern half.

AGRICULTURE.

Outside of Columbus, agriculture is the principal industry. General farming is practiced, but the numerous branches of this vary somewhat in importance in different localities. Thus in the northeastern quarter, the clay soils are best adapted to grazing, and dairying is an important industry. Nearly every village has a creamery and Sunbury a fine one. This phase of the industry is practiced in other areas, but is less important. Columbus is an excellent market for these products.

Except in the northeastern quarter, corn is the principal product of the farms. The rich soils are well adapted to this grain and yield excellent results. The broad valley of the Scioto River south of Columbus is perhaps unsurpassed in the State for this crop. Wheat and oats also are extensively grown, especially on the upland. On the northeastern quarter these grains do better than corn, and with dairying, form the principal industry of the farmers. The southeastern quarter also is a large grower of wheat and oats, these grains dividing honors with corn. The soils in this area vary considerably in fertility, corn flourishing in the richer parts, wheat and oats in nearly all.

With so good a market gardening is naturally an important industry, though the soil cannot be regarded first class for this, being usually too clayey and hard to work. The largest gardens are found south and southeast of Columbus, and also in the valley of the Olentangy from Third Avenue to the northern limit of the city.

The hills in the vicinity of Lithopolis are comparatively poor and not well adapted to grains, especially corn. They yield excellent results, however, with fruits. Berries are extensively grown and to a lesser extent, the larger fruits. The soils are suitable, and the high land gives excellent water and air drainage. Late spring frosts are not common because the cold heavy air slips down the hillsides on the lower tracts. The land along the Olentangy north of Columbus is also well adapted to fruits. The industry there has only been started, but should grow in importance.

FOURTH SERIES, BULLETIN 15

THE DEVONIAN AND MISSISSIPPIAN FORMATIONS OF NORTHEASTERN OHIO

By CHARLES S. PROSSER

December, 1912

2—G. B. 15—per V.

DR. JOHN A. BOWNOCKER, *State Geologist*:

Dear Sir:—I herewith transmit the manuscript for a Bulletin on the stratigraphic geology of a part of this State entitled "The Devonian and Mississippian Formations of Northeastern Ohio." The collection of data for this report and others relating to the stratigraphy of Ohio began in 1901 under Professor Edward Orton, Jr., then State Geologist, and since 1907 has been continued under your administration. In the field work the writer has been assisted by several students of Ohio State University, the names of whom are given in the introduction. It is regretted that the completion of this report has been greatly delayed by other duties. The material is partly in hand for further reports of this character and it is hoped that this may be the first one of a series of bulletins, by the writer, devoted to the stratigraphy of Ohio.

With assurances of my high appreciation of your cordial support of the continuation of this line of geologic investigation, I remain,

Respectfully yours,

CHARLES S. PROSSER.

Ohio State University, Columbus, March 30, 1912.

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INTRODUCTION

Since 1901 the writer has devoted considerable time to the study of the stratigraphy, classification and correlation of the Devonian and Carboniferous formations of northern and central Ohio. The larger number of these formations were first described from exposures occurring in Cuyahoga County, hence this county has become a classic one for the study of these rocks in Ohio. For this reason a number of sections in Cuyahoga County and the adjoining county of Summit on the south are described, and then this belt of formations is followed eastward to Pennsylvania, noting certain changes in that distance and their general equivalence with the formations of northwestern Pennsylvania as described by that State Survey. After this is accomplished the bulletin will return to Cuyahoga County and follow the formations along the line of strike for some distance to the southwestward.

It was the intention after the strike changes to southerly to follow these formations to central Ohio, describing them in a similar way and noting the changes; but at present all of this territory has not been fully studied in the field and it seems advisable to present that part of the work which is essentially complete without waiting for further field work on another part of the area under consideration. Neither has it been possible to make a complete study of the fossils for this report; consequently only a few of the very common or most characteristic species are mentioned. In a future report it is hoped to give a much more complete account of the paleontology of these formations.

This work was begun under the administration of Professor Edward Orton, Jr., as State Geologist, and has been continued under that of his successor, Dr. John A. Bownocker. Other investigations, and the urgent demands of university work, have left the writer far too little time for field work and the preparation of this report; but it is believed the matter here presented will add something to the exact knowledge of the stratigraphy of the Devonian and Carboniferous formations of northeastern Ohio. It is thought that this new and more detailed information will be of use not only to the geologist interested in the systems under discussion or the geology of northeastern Ohio, but also to the business man who may desire information concerning the geological formations and structure of that portion of Ohio herein discussed.

The author's acknowledgments are due Professors Edward Orton, Jr., and John A. Bownocker, who as State Geologists have, by their official support and interest, made the preparation of this bulletin possible. This has included in addition to field work some assistance in visiting several large museums where are to be found the type specimens of various characteristic fossils. Some of the results of this study are in-

cluded in this report, although the descriptions and comparisons of the fossils are not here fully presented. In the field at various times Messrs. Charles H. Flory, John A. Wilkinson, William C. Morse and Clyde R. Miller have assisted greatly in the careful measurement of many of the sections and in other ways which are hereby gratefully acknowledged. The index has been prepared by Miss Gertrude S. Kellicott.

CHAPTER I

THE CUYAHOGA VALLEY

From Cuyahoga Falls the Cuyahoga River, flowing in a general northwesterly direction across the central portions of Summit and Cuyahoga counties, has excavated a valley of considerable depth. At Cuyahoga Falls the banks are high and precipitous, below which it enters a pre-glacial valley and for many miles down this valley the river is bordered by fairly steep hills with occasional cliffs. Many of its tributaries have cut comparatively narrow valleys or gorges through these bordering hills in which the rocks are well shown. On account of these favorable conditions for study a number of sections will be described on the Cuyahoga River and its tributaries from the Lake Shore to Cuyahoga Falls.

Lake Erie Bluff West of Edgewater Park.—The shore of Lake Erie for some miles to the northeast of the mouth of the Cuyahoga River is bordered by Pleistocene deposits. Opposite Cleveland the lower 60 feet of the bluffs was referred by Dr. Newberry to the Erie clay which he described as "a fine, homogeneous, stratified, blue, sandy clay, without fossils so far as has been observed, and with no pebbles or boulders."[1] Superjacent to the Erie clay is a deposit of from "25 to 50 feet of sand, gravel and clay, mostly coarse and porous material, differing greatly in appearance from the underlying bed" which Dr. Newberry termed the Delta sand and stated that it "is intimately associated with the lake ridges and belongs to the same geological period."[2] In addition "Lake Ridges" were described by Dr. Newberry; the lowest and most northerly one, about 100 feet above the level of Lake Erie, was stated to be clearly marked in its course across the city and for many miles to the east and west of Cleveland. This is evidently the one which later was mapped by Professors Newberry and A. A. Wright as the "North Ridge"[3] and what Mr. Leverett has recently described as the beach of Lake Warren which "leads into Cleveland from the west along or near Detroit street, and after crossing the Cuyahoga River lies near Euclid avenue to the east edge of the city."[4] This is obviously the beach described by Mr. Warren Upham under the name

[1]Geo. Surv. Ohio, Vol. I, 1873, p. 175.
[2]Ibid., p. 177.
[3]Ibid, Vol. II, 1874, "Map of Lake Ridges in Lorain and Cuyahoga counties," op. p. 58.
[4]Mon. U. S. Geol. Survey, Vol. XLI, 1902, p. 764.

of the *"Fourth or Euclid Avenue beach,"* which he gave as "passing through the city of Cleveland, nearly along the course of Detroit street and Euclid avenue."[1]

Apparently Mr. Leverett would refer most of the Pleistocene deposit in the vicinity of Cleveland to the glacial lakes, their beaches, the sand and gravel delta of the Cuyahoga and the Wisconsin drift with its moraines. The above explanation of the origin of these deposits is also in general harmony with that of Professor H. P. Cushing, of Western Reserve University.[2] Recently, "the raised beaches of the Berea, Cleveland and Euclid sheets, Ohio," have been minutely described by Professor Frank Carney, particularly those marking the levels of Lakes Maumee, Whittlesey and Warren.[3]

To the west of the Cuyahoga River a considerable portion of the lake shore is marked by cliffs of Paleozoic shales, which are the oldest rocks exposed on the surface in the vicinity of Cleveland. A favorable locality for studying an outcrop of these shales, which may readily be reached from the business center of Cleveland, is the bluff of Lake Erie just west of Edgewater Park and to the north of Lake Avenue. At one point the cliff, which is 36 feet high, is composed mainly of bluish argillaceous shales, although to a considerable extent they are slightly sandy, and part of them are rather greenish in color. At intervals more or less concretionary, slightly calcareous layers occur and there are others which are mainly clay-iron in composition, weathering to a rusty color. The latter, broken up on the lake beach and worn to a more or less lenticular shape, occur in large numbers. In general these shales are comparatively soft, and excellent examples of erosion with the formation of projecting headlands are shown. One of these headlands giving the general appearance of the cliffs is well shown in Plate XL, which is a view of the cliff a short distance west of Edgewater Park. The projecting lines on the cliff indicate the thin, harder layers, while the beach shows abundant specimens of these layers broken up by the waves and mixed with the more or less lenticular clay-iron concretions. In the distance to the east is seen the lower part of the city of Cleveland. From this locality for three miles westward to the mouth of Rocky River these strata form the cliffs of Lake Erie, and at many places they may be advantageously studied. These rocks are comparatively unfossiliferous and at this locality no fossils were found.

The strata composing these cliffs were named "the Erie shale" by Dr. Newberry in 1870,[4] who later stated that to this formation he gave "the name of *Erie shale,* because it forms the shore of Lake Erie nearly all the way from the mouth of the Vermilion to Dunkirk."[5] On account

[1] Bull. Geol. Soc. America, Vol. 7, March, 1896, p. 343.

[2] In Brigham's Suggestions to Teachers designed to accompany a Text-Book of Geology, 1901, pp. 63, 64.

[3] Proc. Ohio State Acad. Science, Vol. V, pt. 4, 1909, pp, 225-253.

[4] Geol. Surv. Ohio, Rept. Prog. in 1869 (1870), pt. 1, p. 20.

[5] Geol. Surv. Ohio, Vol. I, 1873, p. 190.

PLATE XL.

Headland of Chagrin shale on Lake Erie, west of Edgewater Park, Cleveland.

of the admirable exposures of these shales at hundreds of localities in the cliffs bordering Lake Erie this was a most appropriate name; but unfortunately it was preoccupied. Vanuxem in 1842 named one of the divisions of the New York system the "Erie," which was composed of the formations ranging from the Marcellus shale to the Chemung inclusive,[1] and this term was revived with a restricted meaning by Dr. John M. Clarke and Professor Schuchert in 1899, when they applied the term Erian to the New York series composed of the Marcellus shale and the Hamilton beds.[2] In the note regarding Erian they made the following explanation concerning the origin of the term: "The 'Erie division' comprised the formations from the top of the Onondaga limestone to the top of the Chemung. We propose to save the term to the New York nomenclature by reviving it with a restricted meaning."[3] In the second place the term Erie was again preoccupied before its use by Newberry, because Logan in 1863 named one of the Quaternary formations of Ontario the "Erie clay."[4] Finally, the name "Girard shale" was applied by Dr. I. C. White in 1881 to a mass of Devonian shales in Erie County in northwestern Pennsylvania;[5] but as these shales are only equivalent to a portion of Newberry's Erie shale the term could not be used for the Ohio formation. For the above reasons the writer in 1903 proposed for this mass of argillaceous and arenaceous shales with calcareous and iron-bearing layers or concretions, and thin sandstones, the name *Chagrin formation* on account of the excellent exposures on the banks of this river extending from Willoughby nearly to Pleasant Valley.[6] The Chagrin River enters Lake Erie about nineteen miles northeast of the Cuyahoga and, with perhaps the exception of the cliffs on the shore of Lake Erie, there are probably no finer outcrops of the formation to be found than those forming its steep banks. Later, in its appropriate place, the outcrops of the Chargin River will be described in detail.

Dr. Newberry's best description of the Erie shale (Chagrin formation) was published in 1873, in which he divided the exposures in the vicinity of Cleveland into two beds or groups. The most characteristic part of his description is as follows:

"The prevailing lithological character of this deposit is very well shown in the sections of the cliff bordering the Lake in the vicinity of Cleveland; and it is here seen to consist of green, gray and blue shales, generally very soft and fine, interstratified with sheets of micaceous, silvery sandstone from half an inch to two inches in thickness, with flattened, lenticular masses of argillaceous iron ore. * * *

"West of Cleveland the Erie shales are seen to form two beds or groups of strata, of which the upper, nearly 100 feet in thickness, con-

[1]Geol. New York, pt. 3, pp. 13, 170.
[2]Science, N. S., Vol. X, Dec. 15, pp. 876, 877.
[3]Ibid., p. 877.
[4]Geol. Survey Canada, Rept. Prog. from Com. to 1863, pp. 896, 897.
[5]Second Geol. Surv. Pa., Q^4, pp. 117, 118.
[6]Jour. Geology, Vol. XI, pp. 521, 533.

sists of shales such as I have described, with thin bands of sandstone which sometimes are sufficiently thick and firm to be used as flagging The lower series consists almost exclusively of blue and green shales, with thin strata of iron ore, the whole weathering in smooth homogeneous cliffs of which the prevailing color is a greenish gray. These two groups are well exposed in the cliffs which form the lake shore between the Cuyahoga and Rocky River[s]; the lower beds composing that cliff for about three miles west of the Cuyahoga."[1]

The exposures which we have described in the cliff to the west of Edgewater Park belong to the lower beds of the above description of Newberry.

Various wells have been drilled for natural gas in the northern part of Cleveland west of the Cuyahoga River down to the Devonian limestone. The following record of one of these located north of Detroit Street was furnished the writer by Mr. S. S. Hulse:

Record of Cleveland Well North of Detroit Street.

Description.	Thickness. Feet.
Erie shale	300— 350
Light colored shale at top which gradually changes to black shale like the Cleveland	100— 150
Very light gray shale which looks like the Erie	75
Dark colored shale; but near the center is a zone of from 5 to 10 feet of light colored shale	60
Very dark colored shale, like the Huron	200
"Soapstone"	200
Top of Devonian limestone at	1,050— 1,100

Newburg Falls and Quarry.—Succeeding the Chagrin formation is a very bituminous, black and rather massive shale when freshly exposed, but weathering to a fissile one, which is more or less favorably exposed at various localities in and about Cleveland. For the above reason it was very appropriately named the Cleveland shale by Dr. Newberry in 1870;[2] but in this report his description was of the briefest character consisting simply of the statement that it is a "black bituminous shale" from 20 to 60 feet in thickness. The "Report on the Geology of Cuyahoga County," however, published by Dr. Newberry in 1873, contained a more extended account of the Cleveland shale and stated that "this name has been given to the black bituminous shale found in most of the counties of the Reserve, from the Vermillion River to the Pennsylvania line."[3]

Dr. Newberry considered the Cleveland shale as of Carboniferous age and in the 1873 report gave it as the basal formation of the "Waverly

[1]Geol. Surv. Ohio, Vol. I, p. 163.
[2]Geol. Surv. Ohio, Rept. Prog. in 1869 (1870), p. 21.
[3]Geol. Surv. Ohio, Vol. I, p. 189.

Group."[1] It must be remembered, however, that Dr. Newberry drew the line of separation between the Carboniferous and Devonian systems considerably lower than is the custom of most American geologists, so that in the standard New York section the Chemung and Catskill formations of the upper Devonian were in the Carboniferous.[2] In fact, in Dr. Newberry's article on the "Circles of Deposition in American Sedimentary Rocks," published in 1874, he stated that "In all our works on geology the Portage, Chemung and Catskill formations are included in the Devonian system, but in my judgment it would be better to consider the *Portage sandstones*—the upper half of the Portage group—as the true base of the Carboniferous system. Drawing the line at this point, we find the Portage and Chemung forming an indivisible mass of mechanical sediments, which, both in fossils and lithological characters, contrast strongly with the underlying Hamilton, and is evidently the record of a new era in the geological history of the continent. This new group I have called the *Erie*, and I think it will be found to belong, both by its fossils and its physical relations, rather with the Carboniferous than the Devonian system."[3] In Dr. Newberry's "Review of the Geological Structure of Ohio," published four years later, we find the Erie shale given as the oldest formation of the Carboniferous system.[4] In support of this classification Dr. Newberry wrote as follows:

"It is evident that the Erie group is the record of the introduction of a new geological age; and that there are, therefore, reasons for removing it from the Devonian system, where it has hitherto been placed and attaching it to the Carboniferous. This change of classification is also favored by the character of the fossils of the Erie, which are generally different from those of the Hamilton, and resemble and probably shade into those of the Carboniferous system. Hence, it seems that the geological record would be best interpreted by considering the Erie group as the base of the Carboniferous."[5]

In 1880 Dr. Orton reported that the Huron, Erie and Cleveland shales of northern Ohio taken together represented the "great black shale" of central and southern Ohio and argued that it ought to be left undivided in the Devonian. He wrote as follows:

"If the true interpretation of the facts is given in these statements, it is apparent that the Cleveland shale, and the Erie shale as well, makes a very inconvenient boundary between Devonian and Carboniferous time. This boundary would be found at an uncertain depth below the summit of the black shale, and there would seem to be no possibility of saying more than this, that the bottom of the black shale is Devonian and the top Carboniferous. But inasmuch as the

[1]Ibid., p. 184.
[2]Mon. U. S. Geol. Survey, Vol. XVI, 1889, p. 77.
[3]Proc. Am. Assoc. Adv. Sci., Vol. XXII, pt. 2, p. 192.
[4]Geol. Surv. Ohio, Vol. III, 1878, p. 18.
[5]Ibid., p. 19.

fossils upon which the reference of the Cleveland shale to the Carboniferous mainly rests (Geological Survey of Ohio, Vol. II, page 94), do not come from this formation at all, but from the Waverly black shale of southern Ohio, which lies one hundred and twenty-five feet to one hundred and fifty feet higher in the scale, it is to be hoped that the great black shale will be left undivided in the Devonian series. If there is confusion in regard to the name, we can revert to the old designation, viz: Black shale, or we can adopt the name applied to the formation in Kentucky, by Professor Shaler, of the recent geological survey, viz., Ohio shale. On the whole, this last designation seems most appropriate."[1]

Dr. Newberry did not change his opinion concerning the age of the Cleveland shale, for in 1889 he still gave it as the oldest formation of the Waverly group.[2] In discussing the age of the shale in this monograph Dr. Newberry gave his views clearly and positively in the following language:

"As a general rule the Cleveland shale is very barren of fossils, many of its exposures having yielded nothing but the imprints of sea weeds. Aside from the great fishes which are its characteristic fossils, and which, being all new species, do not decide this question, we have not a great array of evidence. In the excellent exposures at Bedford, Ohio, except millions of Conodonts, having no geological significance, the only fossils found are the spines and teeth of three species of Elasmobranchs, *Hoplonchus*, *Orodus*, and *Polyrhizodus*. These three genera are characteristic of the Carboniferous system, and have never been found in the Devonian; but they will hardly be accepted as decisive, being specifically new. To solve this problem, Mr. M. C. Read and Prof. H. P. Cushing have within the last year made diligent search throughout northeastern Ohio for molluscous fossils in the Cleveland shale. Their efforts have been reasonably successful, as they have found large numbers of four species of Brachiopods, three of *Lingula* and one of *Discina*. In order to make the specific determination of these shells as certain as possible, they were submitted, without information as to their origin, to Prof. R. P. Whitfield, whose accuracy and palæontological knowledge are proverbial. He reports them to be *Lingula Cuyahoga*, Hall; *L. melie*, Hall; and *Discina Newberryi*, Hall; all well-known species of the Cuyahoga shale (Upper Waverly). The fourth species, not identified by Professor Whitfield, is a pointed *Lingula*, apparently undescribed, but found in the Bedford shale, which overlies the Cleveland, and is full of Waverly fossils.

"The evidence, then, that the Cleveland shale is the basal member of the Waverly and a part of the Carboniferous system, as stated in the Ohio reports, though not overwhelming, may be considered as satisfactory.

[1]Ann. Rept. Secretary of State [Ohio] for 1879 (1880), p. 594.

[2]Mon. U. S. Geol. Survey, Vol. XVI—The Paleozoic Fishes of North America—p. 120.

"Prof. Edward Orton, the present State geologist of Ohio, has in several of his recently published papers united the Cleveland, Erie, and Huron shales, and called them collectively the Ohio shale. This seems to me unwarranted, as these strata are essentially distinct in their fossils, and the upper and lower members of the trinity are separated on the eastern border of the State by an interval of at least one thousand feet."[1]

Dr. Orton apparently adhered to his opinion and retained the Cleveland shale in the Devonian, drawing the line separating the Devonian and Carboniferous systems between the Cleveland and Bedford shales.[2] This correlation has also been followed in the later reports of the Geological Survey of Ohio.[3]

The same year Dr. Girty in elucidating the Bradfordian series, which he had proposed in an earlier paper, stated that "In Ohio it [Bradfordian] is tentatively assumed to be represented by the Bedford and Cleveland shales, and probably by the Erie. Its age is a matter of some diversity of opinion, but I believe that its true relations are with the Devonian."[4]

Professor Schuchert in his "Paleogeography of North America" makes the Cleveland shale the basal formation of the Kinderhookian series of the Mississippic period emended[5] which equals the "Lower Mississippian or Kinderhook and Osage of geologists."[6] The Bradfordian of Pennsylvania and New York is also put in the lower part of the Kinderhookian, although it is stated that Dr. Girty's correlations are followed in this table for the formations "in the column 'East of Cincinnati axis' " for Ohio and Pennsylvania.[7]

Dr. Ulrich in his "Revision of the Paleozoic Systems" gives the Chagrin formation as the highest Devonian one and the Cleveland shale as the basal one of the "Waverlyan system."[8]

In the summer of 1911 Dr. Edward M. Kindle carefully studied the Ohio shale at various typical localities across Ohio as well as south of the Ohio River in connection with his former field work in Kentucky and Tennessee, and some of his results, as recently published, are of great importance in determining the age of the Cleveland shale. Dr. Kindle's discussion in part is as follows:

"When Professor Newberry found himself unable to substantiate his previously published statement of the occurrence of a Waverly fauna [*Syringothyris typa*, etc.] at the base of the Cleveland shale,

[1]Op. cit., pp. 127, 128.
[2]Geol. Surv. Ohio, Vol. VII, 1893, pp. 4, 22, and "Geological Scale of Ohio" **op. p. 4.**
[3]As for example, see 4th Ser., Bull. 7, 1905, pp. 3, 4, 20-24.
[4]Proc. Washington Acad. Sci., Vol. VII, June 20, 1905, p. 7.
[5]Bull. Geol. Soc. America, Vol. XX, 1910, p. 548.
[6]Ibid., p. 547.
[7]Ibid., pp. 548, 550.
[8]Ibid., Vol. XXII, 1911, pl. 28.

he continued to maintain the Carboniferous age of the formation chiefly on the evidence of the occurrence in it of three genera of Carboniferous fishes, namely, *Hoplonchus*, *Orodus* and *Polyrhizodus*. Concerning this evidence it is well to recall that most of the fossil fishes described by Newberry were obtained for him by collectors on whom he depended for the correct designation of their geologic horizon. Since Professor Newberry had himself confused the Sunbury and Cleveland shales, the opportunities which existed for the collectors to confuse them are too evident to require discussion. If these genera occur in the Cleveland shale at Bedford, as Professor Newberry believed, recent workers in this field should have found at least one or two of them. We have, however, the testimony of two paleoichthyologists, Dr. L. Hussakof and Prof. E. B. Branson, who have been persistent collectors in the Cleveland shale of northern Ohio, that they have never found any of these genera in it. Professor Branson writes as follows:

"'I have never collected any specimens of the genera mentioned in your letter, from the Cleveland shale, nor have I ever seen Carboniferous fish remains of any kind in the shales. * * We had quite a large collection of Cleveland shale material in Oberlin College Museum, but all of it indicated the Devonian age of the formation.'"

"Dr. Hussakof indicates his experience in the following words:

"'In regard to your query about *Hoplonchus*, *Orodus* and *Polyrhizodus* —I have never found any of them in the Cleveland shale.'"

"In view of this kind of testimony from paleontologists thoroughly familiar with the fish fauna of the Cleveland shale, both through extended collecting and study of all the important collections made by others, we seem forced to conclude that the Carboniferous fishes which Newberry records from the Cleveland shale came probably from the Sunbury instead of the Cleveland."[1]

Since the publication of Dr. Kindle's paper, Professor Cushing has defended the accuracy of Dr. Newberry's statement concerning the occurrence of *Hoplonchus*, *Orodus*, and *Polyrhizodus* in the Cleveland shale. He apparently understands Dr. Newberry to state that he collected specimens belonging to all three genera in the Cleveland shale at Bedford.[2] The statements concerning this matter by Dr. Newberry are as follows:

"At Bedford I obtained from this stratum [Cleveland shale] quite a number of fish teeth consisting of species of *Polyrhizodus*, *Cladodus* and *Orodus*; all Carboniferous sharks."[3]

[1]Am. Jour. Sci., 4th ser., Vol. XXXIII, February, 1912, pp. 132, 133.

[2]Ibid., June, 1912, pp. 581, 582 and see particularly his statement on p. 582: "But the matter is finally settled for us by Newberry's definite pronouncement that he collected these fossils *himself*."

[3]Geol. Surv. Ohio, Vol. I, 1873, p. 189.

Later in his monograph on the Paleozoic Fishes of North America, he wrote that:

"In this locality [Bedford] I also obtained small teeth of *Polyrhizodus* and *Orodus* (*P. modestus*, N., and *O. elegantulus*, N. and W.")[1]

Also under the account of the "Fishes of the Cleveland Shale" is the statement that "In the excellent exposures at Bedford, Ohio, except million[s] of Conodonts, having no geological significance, the only fossils found are the spines and teeth of three species of Elasmobranchs, *Hoplonchus*, *Orodus*, and *Polyrhizodus*."[2] The single species of *Hoplonchus* reported from the Cleveland shale (*H. parvulus* Newb.) was originally described under the generic name of *Ctenacanthus* and its formation and locality given as "Cleveland shale, Bedford, Ohio."[3] There is apparently, however, no statement to the effect that it was collected by Dr. Newberry at Bedford.[4]

Dr. Kindle in the above mentioned article makes the following statement concerning the evidence furnished by the conodonts: "A preliminary examination of the conodont fauna of the Huron shale shows that it is very similar to that of the Cleveland shale. The most important facts now available, as bearing directly on the question of the age of the Cleveland shale, relate to the known range outside of Ohio of the species which have been recognized in it. Only three of the Cleveland shale species of conodonts have thus far been recorded from other formations. These are *Prionides angulatus* Hinde, *Prionides erraticus* Hinde, and *Polignathus dubius* Hinde. These species are recorded only from Hamilton and Genesee horizons elsewhere, so that the conodonts, so far as their evidence is recorded, indicate a Devonian age for the Cleveland shale."[5]

Finally, Dr. Kindle's conclusions are as follows: "Briefly summarizing the discussion of the question of the age of the Cleveland shale, we may say that (1) the evidence of the Waverly fauna originally brought forward by Newberry and restated by Bassler should be eliminated from consideration, because neither Newberry nor any of his successors have been able to substantiate it by finding a similar fauna at the base of the Cleveland. (2) Later workers have failed to find any of the Carboniferous fishes claimed by Newberry to occur in it. (3) Some of the large fossil fishes which characterize the Cleveland are represented by identical species in rocks of demonstrated Devonian age. (4) The Cleveland shale conodonts, so far as their range has been recorded, are known elsewhere only from Devonian rocks."[6]

Superjacent to the Cleveland shale is a formation generally composed of soft bluish and chocolate colored argillaceous shale, but in the

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[1]U. S. Geol. Survey, Mon. XVI, 1889, p. 123.
[2]Ibid., p. 128.
[3]Geol. Surv. Ohio, Vol. II, pt. 2, Palæontology, 1875, p. 55.
[4]For Dr. Kindle's answer to Professor Cushing's remarks see Am. Jour. Sci., 4th ser., Vol. XXXIV, August, 1912, pp. 196, 197 f. n.
[5]Am. Jour. Sci., 4th ser., Vol. XXXIII, pp. 134, 135.
[6]Ibid., p. 135.

Cleveland region the lower and middle portions contain blue fine-grained sandstone alternating with shale and to the eastward similar sandstones are found in the upper part of the formation extending even to its top. This formation was named the Bedford shale by Dr. Newberry in 1870, and characterized as a "red and blue clay shale" 60 feet in thickness.[1] The first careful description of the formation was published in the "Report on the Geology of Cuyahoga County" by Dr. Newberry in 1873 in which he stated that "the best exposure of the Bedford shale is at Bedford, and it has received its name from this fact."[2] Later in this report the typical exposures of the Bedford shale in the gorge of Tinkers Creek below the village of Bedford will be described.

The later reports of the Indiana Department of Geology and Natural Resources contain the term "Bedford oölitic limestone" as the name of a formation of the Mississippian series of that state and the question has arisen whether Bedford should be retained as the name for the Indiana or Ohio formation. The claim of priority for the Indiana term rests entirely upon the occurrence of the term "Bedford rock" in Owen's report on Lawrence County, published in 1862, which was not used in the sense of a formation name and was not described. The sentence in which "Bedford rock" occurs is as follows: "The Bedford rock has long been celebrated for its excellent qualities as a building stone, and is extensively shipped; additional localities are being opened, and only require the liberality of railroad directors to furnish switches and other facilities for still more extended sales."[3] The name of Bedford in the above sentence was used in the same sense as the names of hundreds of other towns have been applied to the rock quarried in their vicinity, but without any intention to have them serve as the names of geologic units. In 1896, however, Messrs. Hopkins and Siebenthal formally described a formation of southern Indiana under the name of the "Bedford oölitic limestone."[4] On account of the prior use of Bedford for the Ohio formation Professor Cumings of Indiana University in 1901 proposed "the name Salem limestone for the rocks called Bedford limestone by Hopkins and Siebenthal."[5] The writer held that the Ohio use of Bedford was the one entitled to acceptance; but later he submitted the question to the Committee on Geologic Names of the United States Geological Survey, which has been organized for the consideration of similar questions in geologic classification and nomenclature, and the following decision was transmitted by the former Director Hon. Charles D. Walcott: "(1)That Bedford rock was used by Owen in 1862 in a *Report of Geological Reconnaissance of Indiana,* 1859-

[1]Geol. Surv. Ohio, Rept. Prog. in 1869, p. 21.
[2]Geol. Surv. Ohio, Vol. I, p. 189.
[3]Rept. Geol. Reconnoissance Ind., p. 137.
[4]Twenty-first Ann. Rept. Indiana Dept. Geology and Nat. Res., pp. 291, 298.
[5]Jour. Geology, Vol. IX, April-May, 1901, p. 233. Also see Cumings in Am. Geologist, Vol. XXVII, March, 1901, p. 147.

60, p. 137, but the usage is so indefinite as not to constitute a preemption of the term for stratigraphic purposes. (2)Bedford shale is a term first employed by Newberry in *Ohio Geological Survey Report of Progress*, 1869, p. 21, and this usage should stand. Furthermore, it is understood here that Mr. Cumings has recently proposed to drop the name of Bedford limestone of Indiana, and substitute for it Salem limestone."[1] Both sides of the question were pretty fully presented in the *Journal of Geology* in the April-May number of 1901,[2] and in the closing paper of the series the writer summed up his opinions as follows: "The Bedford shale of Ohio is as thick a formation as the Bedford limestone of Indiana; lithologically it is more sharply limited; it has, apparently, as great areal distribution; as the name of a definite geologic division it has appeared in geological literature for a longer time and to a much greater extent; but it does not contain as valuable economic deposits of building stone."[3] Since the above was written the writer has studied the Salem limestone in the field in southern Indiana and the only modification of the above statement he would make is to suggest that on account of the rapid increase in the use of Bedford shale for bricks and ceramic products, it is not impossible that in the future the economic value of the products from the Bedford shale of Ohio may equal that of those from the Salem limestone of Indiana. In the writer's judgment there is no sound basis for the claim that "Bedford oölitic limestone" should be retained in geologic literature as the name for the Indiana formation and he will continue to use Bedford as the name of the Ohio formation. Later Dr. E. O. Ulrich proposed the name Spergen limestone for the Indiana formation,[4] stating that both Bedford and Salem "are objectionable as formation names, for they are widely and consistently employed as trade names of quarried stone."[5]

Salem limestone was published four years and eight months previous to Spergen limestone, and concerning the point that Salem is used to some extent as a trade name, the same objection could be raised regarding many other well known formations, as for example the Berea grit of Ohio. If there be no other objection, instead of being a disadvantage it is, on the contrary, an advantage that the scientific name of the formation is used for the trade name.

Professor Weller also holds the opinion that Spergen ought not to be substituted for Salem limestone, as may be seen from the following quotation: "Ulrich has rejected both the names Bedford and Salem, and uses the name Spergen limestone for the formation, but the substitution of Spergen for Salem seems to be wholly unwarranted."[6]

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[1]Jour. Geology, Vol. X, 1902, p. 277, f. n.
[2]Op. cit., pp. 215, 232-236, 267-273.
[3]Ibid., p. 272.
[4]Prof. Paper U. S. Geol. Survey, No. 36, 1905, pp. 24, 28-31.
[5]Ibid., p. 30.
[6]Bull. Illinois State Geol. Survey, No. 8, 1907, p. 82.

Dr. Newberry mentioned the falls of the stream at Newburg as one of the places where the Cleveland shale is well shown, and stated that at this locality "scarcely a fragment of it can be found which does not contain scales of fishes."[1] On the preceding page he also stated that the Bedford shale was to be seen at several places in Newburg.

The extension of the city of Cleveland has rendered the gorge and falls at Newburg on Mill Creek less attractive than when studied by Newberry over 30 years ago. It is still, however, readily accessible and the falls are about opposite No. 2770 Broadway, Cleveland, on the A. B. C. division of the Northern Ohio Traction and Light Company. Limited time necessitated a rather hasty study of the falls when the following section was measured.

Section at Newburg Falls.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Euclid lentil of Bedford formation.* Top of sandstone as shown on bank of creek, which is much shattered. Just at the top of the falls some large, calcareous concretions occur. The upper portion of the falls is composed of massive, grayish sandstone alternating with shales. This zone belongs in the lower part of the Bedford formation and as Newberry stated "is the 'blue stone' of the Cleveland market"	19½	49
2.	Argillaceous, bluish-gray shale which is rather gritty, with a thickness of 5 feet 5 inches. Base of Bedford formation	5½ —	29½
1.	*Cleveland shale.* Massive, black, bituminous shale which in the fall occurs in thick layers; but weathers into thin, even laminæ. This black shale continues to the foot of the fall which is the lowest rock seen at this locality.	24	24

In a letter to Prof. James Hall in 1861, Prof. R. P. Whitfield, at that time one of Hall's assistants, reported 58 feet of "black slate" in a section at Newburg. This black slate was overlain by 26 feet of "compact yellowish-gray sandstone" the upper part of which, however, was stated to be thinner bedded to shaly. The thickness of this part of the section is in close agreement with what the writer has given in his section of Newburg Falls.

The Cleveland shale in all the outcrops seen in the Cleveland region on a fresh exposure is very compact and massive for a shale. On weathering, however, it splits up into thin laminæ, which on banks where the talus is slowly removed are of a somewhat rusty color and not markedly different in appearance from the weathered outcrops of the Huron and Sunbury, the two other black shales of Ohio.

The following section of a cliff on Mill Creek about one-fourth mile below Newburg Falls was measured by an assistant, Dr. John A. Wilkinson:

[1]Geol. Surv. Ohio, Vol. I, 1873, p. 189.

Section of Cliff on Mill Creek below Newburg Falls.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
4.	Heavy layer of "blue stone", or fine-grained sandstone. *Euclid sandstone of Bedford formation*	1	10	84	8
3.	Grayish shale containing some very thin sandstone layers	5	4	82	10
2.	*Cleveland shale.* Black, tough, bituminous shale	45	--	77	6
1.	*Chagrin formation.* Bluish-gray, argillaceous shale containing occasional calcareous layers	32	6	32	6
	Creek level.				

The lithologic character and thickness of the Cleveland shale in the above section agree well with Dr. Newberry's description in which he stated that "it is found outcropping in the hills which border the valley of the Cuyahoga, and good exposures of it are seen within the limits of the city of Cleveland. It is there fifty feet in thickness, a homogeneous mass of bituminous shale."[1]

In the Cleveland region the greater part of the lower portion of the Bedford formation is composed of a grayish to bluish fine-grained sandstone alternating with layers of shales, for which Dr. Newberry accepted the trade name and generally called it the "blue stone". Later it has been determined that there is another sandstone zone near the middle of the formation. Considering all the known facts regarding the sandstone zones of the lower and middle portions of the Bedford formation at Euclid, Cleveland, and in the lower Cuyahoga Valley, it appears that they are of lenticular shape and do not extend, so as to be clearly recognizable, for any very considerable distance. For these reasons it has appeared best to call them lentils and for convenience in reference and description to give them geographic names. Dr. Orton in describing the Bedford shale stated that "especially about Cleveland, there are fifteen to twenty feet of valuable stone included in it. This stone is even bedded, very strong and durable, and it supplies a large quantity of flaggings, caps and sills, of the best grade. It is known as the East Cleveland, Euclid and Independence blue-stone."[2] Much later Professor Cushing has briefly described the Bedford shale as "composed of soft blue or red shale" which "about Cleveland contains a 20-foot stratum of sandstone (the Euclid or Bluestone) near the base."[3] This lower sandstone lentil of the Bedford formation is well shown on Euclid Creek in Euclid Township to the northeast of Cleve-

[1]Mon. U. S. Geol. Survey, Vol. XVI, 1889, p. 126.
[2]Geol. Surv. Ohio, Vol. VI, 1888, p. 34.
[3]In Brigham's Suggestions to Teachers designed to accompany a Text-book of Geology, 1901, p. 62.

land, where are the principal quarries, the outcrops of which will be described later, and the name Euclid is adopted for this sandstone lentil of the Bedford formation.

The higher lentil is named the Sagamore from Sagamore Creek in the southwestern part of Bedford Township, on which it is well shown, the sections of which will be given later.

There is some difficulty in defining the limits of these lentils at all the localities where shown; but the writer has applied the names as nearly as possible to those portions of the formation in which the layers of sandstone are of sufficient thickness to be quarried or where sandstones predominate. With this explanation in mind it will be understood that the bottom or top of either lentil in different sections does not necessarily mean that it is drawn at strictly the same stratigraphic horizon.

The statement by Dr. Newberry in the "Report on the Geology of Cuyahoga County" that the "blue stone is the precise geological equivalent of the 'Buena Vista stone' of the Scioto Valley"[1] is a mistake. The Buena Vista member in southern and perhaps central Ohio comprises about the lower fifty feet of the second division of the Cuyahoga terrane for which this name has been revived and redefined by the writer.[2] Recently Prof. J. E. Hyde has studied the Waverly formations of southern Ohio and the results of his work necessitate some modification of the description which the writer gave of the Buena Vista member. Overlying the Bedford formation are the Berea grit and Sunbury shale before reaching the Buena Vista, so that there is no possibility of the Euclid and Buena Vista sandstones being equivalent, although their lithologic characters are very similar. This mistake, however, arose from the fact that Dr. Newberry erroneously correlated the Cleveland shale of northern Ohio with the Sunbury shale (Waverly black slate) of southern Ohio. The story of this mistake, which for a number of years confused all correlations of these formations between northern and southern Ohio, has already been told by the writer.[3]

In the Newburg Falls section zone No. 3 is referred to the Euclid lentil of the Bedford formation, below which is 5 feet 5 inches of argillaceous, bluish-gray shale. A zone of shale either argillaceous or arenaceous, but of variable thickness, usually occurs between the base of the Euclid sandstone and the top of the Cleveland shale.

Not far from the fall is a quarry in Newburg in which the blue or gray fine-grained sandstone of the Euclid lentil of the Bedford formation is well shown. The exposure of 22⅚ feet is composed mainly of fairly thick sandstone layers separated by shale. Some of the layers are not regular and there is evidence of rolled or concretionary struct-

[1] Geol. Surv. Ohio, Vol. I, 1873, p. 189.
[2] Am. Geologist, Vol. XXXIV, Dec. 1904, pp. 341, 342, f. n.
[3] Jour. Geology, Vol. X, 1902, pp. 263-272.

ure somewhat similar to that of certain layers of the Oneonta formation of New York, which have been compared by Dr. John M. Clarke with the "Kramenzel" of Germany.[1] This comparison is only intended to relate to the structure, for they have none of the red or green tints which also characterize the Oneonta and "Kramenzel" deposits.

Section of Newburg Quarry.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
11.	Gray sandstone at top of quarry	--	5	22	8
10.	Bluish, argillaceous shale	--	8	22	3
9.	Massive layer of gray, fine-grained sandstone	6	--	21	7
8.	Massive sandstone	2	9	15	7
7.	Mainly sandstone, but in some parts of the quarry there is some shale	2	2	12	10
6.	Massive sandstone	3	9	10	8
5.	Stratum varying from shale to sandstone	2	3	6	11
4.	Massive sandstone	3	--	4	8
3.	Flaggy sandstone, upper layer 2 inches, lower one 8 inches	--	10	1	8
2.	Shale	--	2	--	10
1.	Sandstone to base of quarry	--	8	--	8

The entire exposure in this quarry belongs in the Euclid lentil of the Bedford formation, which Dr. Newberry called "the 'blue stone' of the Cleveland market."[2] A single reading of the barometer gave a difference of 30 feet from the top of the quarry (No. 11 of the section) to the top of the Cleveland shale in the Newburg Fall. The distance is not far and the dip slight, so that probably 30 feet is not far from the actual thickness of the rocks included between these two horizons.

Big Creek Sections.—On the banks of Big Creek below the Pearl Street bridge at South Brooklyn, as well as in railroad cuttings, are frequent exposures of the Chagrin formation. It consists principally of bluish-gray to gray shales, which on weathering are frequently much iron-stained, with numerous lenticular clay-iron concretions. Above Pearl Street bridge and Brookside Park there are frequent exposures of the Chagrin formation with banks 40 feet or so in height. The greater part of the rock consists of bluish to bluish-gray shales with some clay-iron concretionary layers and thin, micaceous sandstones. The top of the formation is apparently reached in the cliff on the southern side of the creek less than one-fourth mile above Brookside Park, where at 60 feet above creek level, barometrically, weathered black shale occurs in place. The barometer indicates that from the bed of

[1]Thirteenth Ann. Rept. State Geologist, [N. Y.], 1894, p. 538, and N. Y. State Mus., Forty-seventh Ann. Rept., p. 732.
[2]Geol. Surv. Ohio, Vol. I, p. 188.

Big Creek at the railroad bridge (the Pearl Street bridge) up to this horizon the upper 100 feet of the Chagrin formation is shown. Another reading from the level of Big Creek at the South Brooklyn railroad station to the base of the Cleveland shale on the bank of Big Creek at the railroad bridge near West Park Cemetery gave 90 feet of Chagrin.

The transition from the Chagrin formation to the Cleveland shale may be studied to best advantage, however, on the northern bank of Big Creek at West Park Cemetery and just below the most western bridge of the Cleveland, Lorain and Wheeling Railroad shown on the Cleveland quadrangle. Immediately below the small cascade in the run leading from the cemetery the upper 15 feet of the Chagrin formation may be seen. This portion consists largely of thin, micaceous, grayish sandstone layers with somewhat varying thickness which alternate with thin layers of bluish or bluish-gray argillaceous shale, from 1 to 10 inches thick. At the top is a sandstone, in places 3 inches thick, similar in lithologic appearance to the sandstone layers noted below in the Chagrin, but a little thicker than most of them. In the upper 4 feet of the Chagrin are some bluish-black to brownish-black layers of shale which begin to have the lithologic appearance of the Cleveland, and indicate the beginning of the physical conditions under which that shale was deposited. The larger part of the 4 feet, however, consists of rocks with the lithologic characters of the Chagrin, which is especially true of the upper sandstone, so that it has been left in that formation. It is probable, however, that this lithologic change from the typical character of the Chagrin formation is the commencement of that changed condition of deposition which farther west has led to a decided thickening of the black shale, produced in part by the changed lithologic character of the upper Chagrin and in part by a similar lithlogic change of the lower Bedford. It is not thought necessary, however, to assign a new name to these shales, which are lithologically transitional from the Chagrin to the Cleveland. A little farther west where the black color largely predominates they have been included in the Cleveland, and this reference appears to be in harmony with the principles of stratigraphic classification as elucidated by Bailey Willis of the U. S. Geological Survey.[1] The upper surface of the sandstone was taken as the dividing line between the Chagrin and Cleveland formations, succeeding which nearly if not quite all the shale is black with the characteristic lithology of the Cleveland. In the weathered banks the outside of certain layers is covered with grayish or whitish deposits of sulphate of iron; but on digging into the bank the shale is seen to be black. In this locality the line between the Chagrin and Cleveland shales is sharp and well

[1]For his illustration of the way in which this particular type of a formation's boundary may change see Jour. Geology, Vol. IX, 1901, fig. II, on p. 565 and explanation on p. 563.

marked and admits of a ready separation into two formations. The Cleveland shale is also shown in the C. L. & W. R. R. cut to the east of the bridge. The upper few feet of the Chagrin formation extend up the creek above the railroad bridge, where on the eastern bank of the bend in the creek the overlying black shale to the top of the cliff was measured. The top of the Cleveland shale was not shown, but the bank measured with steel tape gave 51½ feet of black shale, which is a little greater than the actual thickness, because the bank is not perfectly vertical. It, however, showed that there is some 50 feet of Cleveland shale in this bank. Farther up the stream where the upper sandstone and shale of the Chagrin formation make the floor of the creek, the almost vertical bank of black shale was again measured with steel tape, giving 56½ feet, apparently all Cleveland. The shale very near the top of the bank as seen from the creek below is apparently all black, so that it appears perfectly safe to state that on Big Creek the Cleveland shale has a thickness of at least 55 feet.

A little below the place just cited is an uplift and near the axis of the fold the shales are broken, forming a reverse fault. Another anticlinal fold with a reverse fault near its axis occurs farther up the creek and on the opposite side, where the throw is about 2 feet. Still farther up the stream, above the railroad cut and near the western line of the Cleveland quadrangle, is another sharp anticline which is also faulted. At this locality a gray micaceous sandstone with bluish-gray argillaceous shale below is brought up, both of which closely resemble the upper part of the Chagrin formation as shown farther down the stream. These rather frequent folds and faults in the shale render some care necessary in determining the thickness of the various sections. It is hardly safe to assume for any considerable covered distance that the same conditions continue as noted on each side, and even in following a continuous exposure it is necessary to watch for folding, rapid change in dip or faulting. The faults and anticlines on Big Creek would lead to an erroneous estimate of the thickness if determined by following the stream continuously with a hand level or reading the barometer.

Somewhat similar anticlinal folds in the Chagrin shales shown in the cuts of the Belt Line Railroad in Cleveland have been described and illustrated by Prof. Frank R. Van Horn.[1] The Professor's explanation of their formation is that they "were probably caused by pressure due to the nearly threefold increase in volume which results when iron sulfides alter to iron sulfate and alum-like compounds."[2]

A short distance up the creek from the anticline just described in the midst of fine black Cleveland shale, as weathered on the cliff, is an occasional layer of light gray, micaceous sandstone about one-half inch

[1]Bull. Geol. Soc. America, Vol. XXI, No. 4, Dec. 1910, pp. 771-773, pls. 53 and 54.
[2]Ibid., p. 772.

in thickness. There is also an occasional thin layer of bluish-gray argillaceous shale, showing that this part of the Cleveland is not composed entirely of black shale. In the bed of the creek not far below the first highway bridge above West Park Cemetery, is a layer of bluish-gray micaceous sandstone nearly two inches thick. According to the barometer this sandstone layer is 30 feet above the base of the black shale, while cliffs of black shale from 25 to 30 feet high rise above it. The grayish sandstone and shale, however, form so small a percentage of the total thickness of the lower black shales on this stream that it is believed they may be referred to the Cleveland shale in accordance with the definition of a formation by Bailey Willis and they are so included by the writer.

The top of the Cleveland shale is reached on Big Creek some two miles south of North Linndale, south of the second east and west road crossing the creek and a few rods south of the brick schoolhouse on the Linndale-Parma highway. Again the top of the shale is shown in the bed of Big Creek just below the house of Jacob Kraus. The barometer read at the base and top of the black shale gave a difference in altitude of 70 feet, which indicates the thickness of the Cleveland shale in this section. A little later it will be shown that in the Doan Brook section on Ambler Boulevard near Case School in Cleveland, between 8 and 9 miles to the northeast, the Cleveland shale is only 37½ feet thick. This thickening of the black shale as it is followed to the southwest is due largely to the downward encroachment of the black deposits upon the Chagrin, as is shown by the presence of thin sandstones and shales with the lithologic appearance of the Chagrin in the lower portion of the black shale deposits on this creek. There also may be some encroachment upward of the black shale deposits upon the Bedford formation.

Section on Big Creek.

No.		Thickness. Feet.	Total thickness. Feet.
8.	*Berea sandstone.* From the outcrop in the highway gutter near the bridge over Big Creek northwest of Parma, where are cliffs of Berea sandstone. It is 20 feet lower according to the barometer to the base of the formation as shown some rods farther down the stream. This lower portion of the Berea is fairly coarse and more or less irregularly bedded, composed of coarse quartz sand, some of which is rather loosely cemented. When weathered there is a large number of iron spots and to some extent the surface of the cliff is covered with calcite	20	291
7.	*Bedford formation.* At the top is a zone of gray, argillaceous shale. Below this upper zone, so far as shown, the shale is chocolate colored, argillaceous and breaks up into thin small pieces as it weathers. The thickness of this pencil shale according to the barometer readings, is between 55 and 60 feet. The base of this		

No.		Thickness. Feet.	Total thickness. Feet.
	zone is shown on Big Creek about one-half mile below the first east and west road north of Parma and about opposite the house of J. Emrich on road west of the creek. The Berea rests unevenly on the Bedford with sags and arches similar to those on Skinner's Run in the eastern part of the township, $3\frac{1}{2}$ miles farther east, which are described farther on in this bulletin, only the vertical distance is not so great. At the northern end of this outcrop there is a sag of 3± feet in the base of the Berea into the Bedford shale	60	271
6.	Some chocolate colored shale; but mostly bluish-gray shales and thin sandstones	20	211
5.	Bluish to olive argillaceous and arenaceous shales with layers of thin sandstone in lower part of zone, some of which are ripple-marked. This zone is shown on the bank a few rods below the railroad bridge	11±	191
4.	Bluish, fine-grained sandstone alternating with shale, 7 feet 10 inches thick	$7\frac{5}{6}$	180 −
3.	The basal zone of the Bedford consists in the main of dark gray shale, part of which is gritty and some of which is argillaceous. At the base is a coarse, blocky, some what calcareous, very dark gray to blackish shale which is 2± inches in thickness. This shale is coarser and harder than that above, is fossiliferous and contains specimens of *Orbiculoidea* and a few other fossils. A little farther up the creek than at the place where this shale was first noticed, and on the opposite side, a pyritiferous sandstone, 4 inches thick, appears in the lowest shale. This sandstone is very inconstant, thinning out and reappearing. On Ambler Boulevard, Cleveland, between 8 and 9 miles to the northeast, there is 3 feet 9 inches of blue shale at the base of the Bedford before reaching the base of the lowest sandstone layer	$2\frac{1}{12}$	172 +
2.	*Cleveland shale*. Composed almost entirely of black shale; but with occasional thin layers of bluish-gray, argillaceous shale and light-gray, micaceous sandstone from $\frac{1}{2}$ to 2 inches thick	70	170
1.	*Chagrin formation*. Bluish to bluish-gray shales and thin, micaceous sandstones with numerous lenticular clay-iron concretions. The upper 100 feet of the formation is shown from near the Pearl Street bridge at South Brooklyn up the stream to the Cleveland shale	100	100

The Berea sandstone is shown on a branch of Big Creek at the three corners, three-eighths of a mile southeast of Parma, where it is strongly cross-bedded in structure. The Berea sandstone and higher formations are fully described later in this bulletin. From the top of this outcrop down to the base on Big Creek northwest of Parma the barometer gave a difference of 55 feet, which probably does not represent the entire thickness of the Berea at Parma. At the four corners

one and one-fourth miles to the east and between 65 and 70 feet higher the Brecksville shale outcrops. The base of the Berea is also shown on an eastern branch of Big Creek one and one-half miles northeast of Parma in the angle between the northeast road and the first east and west one north of Parma and one-fourth mile east of the house of Henry Williams. The chocolate colored shale is shown on the branch 10 feet lower than the sandstone and the base of this upper zone of chocolate shale on Big Creek is 55 feet lower than the sandstone.

On Baldwin Creek in the southeastern part of Middleburg Township and two miles southwest of Parma are banks of Brecksville shale from 15 to 20 feet in height.

On the most northern east and west road in Royalton Township and about one-fourth mile east of the north and south road from Parma is fine-grained, bluish-gray, micaceous sandstone, which weathers to a rusty color. This horizon is approximately 150 feet higher than the highest outcrops of the Berea sandstone at the three corners southeast of Parma and is near the base of the Royalton formation.[1] This interpretation is supported by the section on Broadview Road between Parma and Independence townships, about 4 miles to the northeast, where it is 155 feet from the lowest sandstone of the Royalton formation down to the top of the Berea. This interval is that of the Orangeville formation, the thickness of which in these two sections is apparently in close agreement. From the locality just described in the northern part of Royalton Township on up the hill to the north and south road and then toward North Royalton thin-bedded sandstones alternating with shales to near the top of the hill are shown more or less frequently. These outcrops belong in the Royalton formation which was named particularly from the outcrops in the streams on the western slope of this hill. The top of the hill on the road about one-half mile north of North Royalton is by the barometer 245 feet higher than the lowest sandstone noted on the east and west road near the northern line of the township. The higher portion of the hill is well covered by drift, so that the older rocks are not shown and it is hardly safe to refer all of it to the Royalton formation. The Sharon conglomerate outcrops near Walling Corners, 3 miles to the northeast and some 90 feet lower, although the writer has not seen it on the North Royalton hill.

In a gully about one-half mile west of this highest point on the North Royalton road and 185 feet lower (barometer) is an outcrop of an impure limestone, which is similar in lithologic appearance to the Meadville limestones of northwestern Pennsylvania and is described in the section northwest of North Royalton.

The following diagrammatic section shows the thickness of the exposed formations from the Pearl Street bridge at South Brooklyn up Big Creek to Parma and then south to the top of the North Royalton

[1]The Royalton is named and defined in Chapter V of this bulletin (p. 725).

hill. The thickness in part was determined from barometric readings:

General Section from South Brooklyn up Big Creek to Top of North Royalton Hill.

Elevation	Thickness	Formation
721′		Top of North Royalton hill
	245′	Drift. Royalton formation may not extend to upper part of section Royalton formation
476′	150′±	Orangeville formation
326′	55′+	Berea sandstone
271′	101′±	Bedford formation
170′	70′	Cleveland shale
100′	100′	Chagrin formation (upper part)
0′		Big Creek at Pearl Street bridge

Section Near Kinsman Street Reservoir. — The Kinsman Street or High Service Reservoir is on the plateau to the east of the end of the Kinsman and Fulton streets car line about four miles south of Lake Erie, 325 feet above it, and five miles from the Public Square, Cleveland. The plateau is underlain by the massive Berea grit, while the small stream, quarry and street cuttings below afford some opportunity for examining the Berea and Bedford formations. The red Bedford shale is shown on the street near the foot of the sharper rise and its base in the run to the north of Kinsman Street on the Huron property and its contact with the Berea grit in the old quarry. The sewer on Woodland Hills Avenue and the Dean quarry show the sandstone or Euclid lentil of the Bedford formation. The following somewhat composite section has been prepared from the reservoir down to the base of the Dean quarry:

Section from Kinsman Street Reservoir to Base of Dean Quarry.

No.		Thickness. Feet.	Total Thickness. Feet.
5.	Reservoir walk, 325 feet above Lake Erie. Covered interval	52	135
4.	Coarse, gray sandstone which is very much cross-bedded and shattered. Apparently the Berea grit, some of which is fairly massive and has been quarried to a slight extent	13½	83

No.		Thickness. Feet.	Total Thickness. Feet.
3.	*Bedford formation.* Gray, argillaceous shale at contact. Lower is chocolate colored, very fine-grained, argillaceous shale which breaks up on weathering into small, pencil-like pieces	$14\frac{1}{2}$	$69\frac{1}{2}$
2.	Olive and bluish, argillaceous shale below which are bluish-gray sandstones and shales. In the run, at the side of the street before reaching the corner where the Kinsman Street car line stops, are thin-bedded, bluish-gray sandstones which show frequent ripple-marks, mud-flows and apparently other evidence of shallow water. Some of the blocks weather to a very rusty color. In the sewer on Woodland Hills Avenue, bluish-gray sandstone and shale are well shown in excavation	41	55
1.	Bluish-gray sandstone and bluish shale, mainly sandstone with shale partings. This zone extends to the floor of the Dean quarry and with the lower part of the superjacent one belongs in the Euclid lentil of the Bedford formation	14	14

The following more detailed account of Dean's quarry, which is just east of Rockland Avenue, will be given:

Section of Dean's Quarry.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
6.	Till to top of bank	10	--	24	--
5.	*Euclid lentil of Bedford formation.* Sandstone with blue shale partings, two principal sandstone layers	4	--	14	--
4.	Thick layer of bluish, fine-grained sandstone	2	6	10	--
3.	Thin-bedded sandstone with blue shale partings	2	7	7	6
2.	Massive, bluish-gray, fine-grained sandstone	3	2	4	11
1.	Thin layer of shale at top; below is a 10-inch sandstone layer with a 5-inch one at the bottom	1	9	1	9

The floor of Dean's quarry is a bluish-gray, somewhat arenaceous shale; but Mr. Dean told me that a little deeper is a black shale which evidently is the top of the Cleveland. It was seen in an excavation a little lower down the street, and Mr. Dean said it continued to the railroad track. It is shown in several places in the street cuttings and from the railroad track to its highest exposure the hand-level gave $21\frac{1}{2}$ feet.

The coarse sandstone mentioned in the small quarry below the Kinsman Street Reservoir and in street cutting, which is apparently the Berea grit, is the youngest formation outcropping in the immediate vicinity of Cleveland with the exception of the glacial and alluvial de-

posits. The Berea grit was named by Dr. Newberry in 1870 from the large quarries at Berea to the southwest of Cleveland.[1] It was described in his "Report on the Geology of Cuyahoga County," where he stated that it "is a bed of sandstone something like 60 feet in thickness, varying much in character in different localities * * * * which, from the locality that has rendered it most famous, I have called the Berea grit."[2]

A general account of the distribution of "The Berea Sandstone of Ohio" was published by Dr. Orton in a Report of the Secretary of State of Ohio,[3] in which he described its course, stating that "it enters the State from Pennsylvania in Williamsfield, the southeastern township of Ashtabula County[4] * * * and passes through Franklin, Meigs, Jefferson, and Green townships of Adams County to the Ohio River, which it overhangs in bold highlands, between the mouth of Brush Creek and the village of Rockville."[5] A further account appeared in the Secretary's report for the following year,[6] which also contained a page map of "Eastern Ohio" on which the northern and western boundary of the Berea grit was shown by a black line running across the entire state.[7]

These two papers by Dr. Orton, on account of their publication in the reports of the Secretary of State, which are devoted mainly to the publication of the tables of statistics for that department, were practically buried and known to but few geologists.

Doan Brook Sections.—On the bank of Doan Brook, just below the campus of Case School, may be seen perhaps 20 feet of bluish-gray argillaceous shale with an occasional layer of calcareous clay-iron concretions, which more infrequently forms a continuous stratum, belonging in the Chagrin formation. Thence up the brook outcrops of varying thickness frequently occur; the most important of these is just above the New York, Chicago and St. Louis Railroad bridge, where a bank of Chagrin shale of bluish-gray or gray color, with an occasional thin sandstone layer, is shown. There is a strong southerly dip at this locality and probably 35 feet or more of the shales may be measured. This bank gives one a clear idea of the general weathered appearance of the Chagrin formation as seen on the higher banks of the Chagrin River or in other deeper streams both to the east and west of Cleveland.

On the eastern side of Ambler Boulevard starting up the hill southeast of Case School and Adelbert College, is a conspicuous cliff, composed in large part of the Cleveland shale and capped at its southeastern end by the lower part of the Euclid lentil of the Bedford formation.

[1]Geol. Surv. Ohio, Rept. Prog. in 1869, (1870), pt. 1, p. 21.
[2]Geol. Surv. Ohio, Vol. I, 1873, p. 186.
[3]Ann. Rept. Secretary of State [Ohio] for 1878 (1879), pp. 591-599.
[4]Ibid., p. 595.
[5]Ibid., p. 598.
[6]Ann. Rept. Secretary of State [Ohio] for 1879, (1880), pp. 595-599.
[7]Op. cit., op. p. 592.

At the northwestern end of the bluff there is a very strong dip to the south which decreases as followed southward along the bluff. It shows that the northwestern end is apparently on one side of a small but sharp anticlinal fold. These frequent small folds in the shale of this region indicate that caution must be exercised in measuring sections that extend for any considerable distance, as has already been stated in the description of Big Creek.

The rocks of this cliff were studied and measured and the section extended to the level of Doan Brook, although on the bank below Ambler Avenue at this locality the rocks are mainly covered until the creek is reached.

Section of Cliff on Ambler Boulevard.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
10.	Soil and drift to top of bank below house	--	--	--	--
9.	*Euclid lentil of Bedford formation.* Grayish, fairly thick-bedded sandstone	5	2	99	8
8.	Bluish shales which are arenaceous at the top and the remainder argillaceous varying from 3½ to 4 feet	3	6	94	6
7.	Gray sandstone stratum, about 8 inches thick	--	8±	91	--
6.	Bluish shales with some layers of thin, gray sandstone, varying in thickness from 4 feet to 4 feet 1 inch	4	--	90	4
5.	Gray, medium-grained sandstone, varying in thickness from 13 to 15 inches. Base of *Euclid lentil*	1	1	86	4
4.	Blue, argillaceous shale which splits into thin pieces. Very near the base of the zone the shale is a little coarser and fairly fossiliferous	3	9	85	3
3.	*Cleveland shale.* Contact of Cleveland shale and Bedford formation is well shown. The shale is mainly black and on weathering splits into thin pieces that are often of rusty color outside, but black within. There are thin zones on surface of the shale bank which are grayish or light colored; but these are apparently mainly, if not entirely, due to weathering, since on digging into the bank the color is found to be black. The thickness of 37½ feet is less than the usual thickness of the Cleveland shale in Cleveland and perhaps the entire thickness was not obtained in this cliff which is not easily measured	37	6	81	6
2.	Thin-bedded, micaceous sandstone in the lower part of the cliff near its northwestern end which is considered the top				

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
	of the *Chagrin formation*. Below are grayish to bluish-gray, soft shales with an occasional thin layer of brownish-black to black shale, all of it alternating with thin, grayish, micaceous sandstone. At this end of the cliff about 5 feet is shown above the Boulevard, while below the rock is mainly covered until Doan Brook is reached	5	--	44	--
1.	The base of the section is the bed of Doan Brook about opposite the northwestern end of the cliff and most of this zone is concealed by soil until the brook is reached in which are typical exposures of the Chagrin formation	39	--	39	--

The base of zone No. 5 has been taken as the base of the Euclid lentil on account of its thickness, which is greater than a foot. The overlying 8 feet 2 inches consists largely of shales, with the exception of a sandstone stratum near the middle about 8 inches in thickness, and on this account perhaps it would be as well to consider the base of zone No. 9, which, so far as exposed, consists of fairly thick-bedded sandstone, as the base of the lentil.

From the harder layer very near the base of the Bedford formation (near the base of zone No. 4 of the section) the following species were collected:

1. Palæoneilo bedfordensis Meek .... (c)[1]
2. Orbiculoidea sp. .... (rr)
   Small form which has been referred to *O. newberryi* Hall in the Bedford lists; but probably is more nearly related to *O. herzeri* Hall and Clarke.
3. Lingula sp. .... (rr)
   Large specimen badly crushed and distorted which is larger than *L. membranacea* Winch.
4. Chonetes sp. .... (rr)
   Specimens too poorly preserved for specific identification.
5. Cypricardella bellistriata (Con.) .... (rr)
6. (?) Modiella sp. .... (rr)
   Two small and imperfect specimens which resemble somewhat *M. pygmaæ* (Con.); but they are smaller than normal specimens of that species.

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[1]In this list and the following ones the letter or letters following the name of a species indicate its abundance at that locality. The letters used with their significance are given below:

aa = very abundant.
a = abundant.
c = common.
r = rare.
rr = very rare.

7. Goniatites sp. -- (rr)
   A single fragment; but apparently similar to the one from the Bedford figured by Herrick in Geol. Surv. Ohio, Vol. VII, pl. XX, fig. 5.

A loose exfoliated specimen of *Parallelodon hamiltoniæ* Hall, apparently from the thin sandstones a little higher in the cliff was also obtained.

Just north of the New York, Chicago and St. Louis Railroad, Cedar Avenue is followed by the Gates Mill cars of the Eastern Ohio Traction Co., and not far from the section just described, it affords fair exposures of the Chagrin formation, Cleveland shale and Euclid lentil of the Bedford formation as it passes from the lower to the higher ground. The soft bluish-gray shales of the Chagrin formation may be seen on the banks of Doan Brook nearly opposite the southern part of the campus of Case School and in the lower cuttings of Cedar Avenue. Next higher comes the Cleveland shale, which is best seen in the cuttings by the side of the avenue, while on the higher ground and capping the terrace is the Euclid lentil of the Bedford formation composed of shales and sandstones. The sandstones and alternating shales of the Euclid lentil are shown in the trench by the side of the avenue while on the higher ground a short distance from the street the Euclid sandstones have been quarried to some extent. These exposures of the Chagrin formation, Cleveland shale and Euclid lentil of the Bedford formation can be plainly seen from the cars of the Eastern Ohio Traction Co. en route to Gates Mill, Chardon or Middlefield.

Above the Euclid sandstone is red Bedford shale as was clearly shown in the summer of 1906 in the grading by the Eastern Ohio Traction Co. for its Gates Mill division on Cedar Avenue and Mayfield Road. The red shale was shown for a considerable distance near the surface where the track was being lowered. On higher ground, and also on the highway, the Berea grit occurs.

Doan Brook was followed up stream and not many rods above the foot of the Ambler Boulevard cliff section, which has just been described, the top of the Chagrin formation is shown on the west bank of the brook capped by the Cleveland shale and a little farther up is a small cascade in the face of which the contact of these two formations occurs. The barometer gave the contact as 20 feet higher than the bed of the brook at the base of the Ambler Boulevard cliff section which would indicate a southerly dip of about 24 feet in that distance. The western bank is steep above the cascade and affords a good opportunity to measure the entire Cleveland shale, the top of which is reached a little below that street and Indian Fort.

Section of Doan Brook Bank below Indian Fort.

No.		Thickness. Feet.	Total thickness. Feet.
	Top of western bank at Indian Fort.		
4.	*Euclid lentil of Bedford formation.* Partly covered, but so far as shown mainly medium-grained, light-gray sandstone	23	80
3.	Blue, argillaceous shale	$3\frac{3}{4}$	57
2.	*Cleveland shale.* Black, bituminous shale with the exception that in the lower part is an occasional thin layer of light-gray, soft, argillaceous shale	$51\frac{3}{4}$	$53\frac{1}{4}$
1.	Top of *Chagrin formation* in face of small cascade in Doan Brook. Soft, argillaceous, bluish-gray shale	$1\frac{1}{2}$	$1\frac{1}{2}$

Continuing up Doan Brook the banks are partly covered by soil and there is a completely covered interval for several rods extending nearly to the stone arch bridge where the street crosses the brook near Ambler Heights. Bluish-gray sandstones and shales are shown on the eastern bank just below and above the stone bridge. At the base is an 8-inch sandstone which, if it be the lowest sandstone layer in the Euclid lentil, is 3 feet 9 inches above the base of the Bedford formation. The quarry stone of the Euclid lentil is well shown on the bank above the stone bridge, which also forms a small fall in the brook and a little farther up, on the western side, was formerly quarried. The upper part of the eastern bank at Ambler Heights shows the reddish, argillaceous shale of the Bedford formation, which apparently underlies some portion of this territory. This section is interesting since it gives the approximate thickness of the Euclid lentil of the Bedford formation.

Section of Doan Brook Bank from the Stone Bridge to Ambler Heights.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
5.	Reddish or chocolate colored, soft, argillaceous shale of the *Bedford formation*, forming upper part of the bank. Lower part of zone also composed of soft, argillaceous shale; but it weathers to a buff color	8	9	54+	--
4.	Mainly bluish-gray, arenaceous shales and sandstones which are thin, none of them much more than 4 inches in thickness	12	2	45	5
3.	*Top of Euclid lentil of Bedford formation.* Composed mainly of gray to bluish-gray, fine-grained sandstone or freestone. There are some thin shale partings principally in the lower part and the greater portion above the lower $2\frac{1}{3}$ feet is fairly thick-bedded, massive sandstone. One layer near the top is 2 feet 8				

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
	inches in thickness. This zone is shown on the bank above the stone bridge	23	3	33	3
2.	Composed principally of bluish-gray, rather arenaceous shale containing thin layers of sandstone. Near the middle of the zone one layer of sandstone is 5 inches thick. Part of this zone is shown just above the bridge and all of it just below.	9	4	10	--
1.	Gray, sandstone layer which is perhaps the lowest sandstone in the Euclid lentil	--	8	--	8

The above section gives 33 feet 3 inches of rocks belonging in the Euclid lentil below which, at least, is the zone of blue, argillaceous shale, 3 feet 9 inches in thickness in the lower sections of Doan Brook, before reaching the Cleveland shale, which indicates that at least 37 feet of the Bedford formation is shown on Doan Brook. The top of the Euclid lentil is drawn where the massive sandstone ends and the superjacent zone, containing more shale than sandstone, begins. This line of division between the massive sandstones and the succeeding bluish-gray arenaceous shales containing thin sandstones, none of which is more than 4 inches in thickness, is drawn at a lithologic change which at this locality is fully as marked as the boundary between many formations. Likewise the bottom of the Euclid lentil is drawn at the base of the lowest sandstone of any considerable thickness, below which is a blue argillaceous shale of variable thickness in the Cleveland region extending down to the top of the Cleveland shale.

Euclid Creek and Township Sections.—Euclid Creek, like Doan Brook, is not a tributary of the Cuyahoga River, but flows into Lake Erie. This creek has cut a deep gorge in which the upper part of the Chagrin formation is admirably shown together with the Cleveland shale, Bedford formation and Berea grit. On account of these excellent outcrops which admirably supplement the exposures already described in Cleveland, the gorge of Euclid Creek and Township will be considered before continuing with the Cuyahoga Valley southward from Cleveland.

The study of the rocks exposed on Euclid Creek began at the lower end of the gorge at the stone viaduct just west of Euclid. According to the Euclid sheet of the U. S. Topographic Atlas the bed of the creek at this locality is some 45 feet higher than Lake Erie. The creek has cut a trench about 7 feet deep just below the viaduct in the blue, soft, argillaceous shale of the Chagrin formation. The usual calcareous lenticular concretions are present. This small trench, and the high banks farther up the creek, afford an excellent opportunity to examine and study typical outcrops of the Chagrin shale at a locality which is readily reached from the traction cars of the Cleveland, Painesville and Eastern Railroad.

If one follows the lower road leading up Euclid Creek a bank of Chagrin shale some 60 feet high is soon reached on the western side of the stream, a short distance above the first iron bridge. The bank is composed almost entirely of blue, very soft, argillaceous shale with an occasional layer of lenticular concretions which are somewhat calcareous and on weathering become rusty in color on the outside. The bank is steep with almost smooth surface, which is broken only by the calcareous layers. Apparently all the rock of this bank belongs in the upper part of the Chagrin formation, with the exception of the overlying drift and soil.

On the eastern side of the creek above the second iron bridge crossing it and below its principal eastern branch is a still higher bank of the Chagrin shale capped by the tougher Cleveland shale. This is an admirable exposure showing fully 70 feet of Chagrin shale conspicuously capped by 5 feet or more of the Cleveland shale. The topographic map apparently gives the height of this cliff as some 120 feet; consequently the above estimate, *not measurement,* of the thickness of the shales is probably too small. The Chagrin, like that of the lower cliff, is composed of soft shales with an occasional thin, harder layer. These banks, although probably not so high as those of the Chagrin River from which locality the formation has been named, nevertheless furnish fully as good an opportunity for studying its characteristics.

Another excellent outcrop is farther up the creek on its eastern bank, below Dr. Corlett's house, where there is a steep cliff showing 110 feet of Chagrin capped by 33 feet of Cleveland shale as measured by an assistant, Mr. William C. Morse. As the Cleveland shale is tougher than the Chagrin, when it overlies the latter it usually forms the steeper part of the cliff which also projects slightly at the sharp line of contact. These characteristics are beautifully shown in this cliff and may be seen in the accompanying half-tone of this bank in Plate XLI.

The base of the Cleveland shale occurs near the bottom of the western bank of the creek about 2¼ miles above the stone viaduct at Euclid and a short distance below the C. H. Burgess quarry, which is the northern one of the series of quarries located on its bank. The barometer gave the contact of these two formations as 160 feet higher than the bed of Euclid Creek at the stone viaduct, all of which belongs in the upper portion of the Chagrin formation. The top of the Cleveland formation occurs only a few rods farther south on the same bank and it is composed essentially of rather thick bituminous black shale. The barometer gave a thickness of 60 feet for the Cleveland shale on this bank, while by hand level Dr. Wilkinson made it 58 feet 3 inches. Dr. Newberry in his "Section on Euclid Creek" gave the thickness of No. 4 as 60 feet which he described as "Black bituminous shale (Cleveland shale), source of oil and gas."[1] Within about two feet of its top,

[1]Geol. Surv. Ohio, Vol. I, p. 198.

specimens of *Lingula* were found, although not in any particular abundance. Some of them are probably identical with those reported from the Cleveland shale by Prof. R. P. Whitfield as *Lingula melie* Hall.[1] After studying a large number of specimens of this species from the typical localities of Chagrin Falls and Berea the writer is convinced that these specimens from Euclid Creek can not be distinguished from *L. melie* Hall. They clearly show the flattened space which extends from the umbo, gradually widening, to the ventral margin. Exfoliated specimens also show the radiating striæ and other characters which Hall gave in the description, and again the size and outline agree with the majority of the Chagrin Falls specimens. It is to be remembered, however, that Professor Williams reported "*Lingula spatulata* third variety, in the Cleveland shale" in his Painesville, Ohio, section, which he evidently considered as the characteristic species of the black shale fauna that he named B^3.[2]

In addition to *Lingula melie* Hall in the Cleveland shale, Professor Whitfield also reported *L. cuyahoga* Hall, *Discina* [*Orbiculoidea*] *newberryi* (Hall), and "a pointed *Lingula*, apparently undescribed."[3]

The Cleveland shale on this bank is directly succeeded by sandy deposits instead of the fine, blue shales noted in the Cleveland sections at the base of the Bedford formation. The lower sandstones, which are not very thick, contain a considerable amount of marcasite and alternate with arenaceous shales. On this bank 28 feet of the Bedford formation was measured from the top of the Cleveland shale to the highest outcrop on the bank below the office of Mr. C. H. Burgess. The major part of the rock is fine-grained sandstone, although in the lower part of the member it alternates with considerable shale. Just a short distance south of the office is the C. H. Burgess quarry, which is worked entirely for crushing since the sandstone is too much shattered to be used for either building or flagging.

Some rods farther up Euclid Creek is a fall and at this locality on the eastern bank just above the fall the upper portion of the Cleveland shale and the lower part of the Bedford formation may be readily examined. The contact is finely shown and the base of the Bedford formation resting directly on the Cleveland black shale is a sandy, perhaps slightly calcareous, layer from 3 to 3½ inches in thickness which in its upper part contains a considerable fauna composed principally of Pelecypod shells, but with a few specimens of Gastropods and Cephalopods. Although some search was made in the overlying rocks no fossils were found. In its position it is quite similar to that at the base of the

[1] Mon. U. S. Geol. Survey, Vol. XVI, 1889, p. 128.
[2] Proc. Am. Assoc. Adv. Sci., Vol. XXXIV, 1886, p. 226 and section II of the Chart of "Meridional sections of the upper Devonian deposits of New York, Pennsylvania and Ohio."
[3] Loc. cit.

East bank of Euclid Creek showing Chagrin shale capped by Cleveland shale. See page 363.

Bedford shale in central Ohio. The following species were collected from this layer at this locality:

1. Palæoneilo bedfordensis Meek ---------------------------------- (a)

2. Parallelodon hamiltoniæ (Hall)---------------------------------- (c)
   These specimens are apparently identical with the one represented by fig. 7, pl. 51, Lamellibranchiata II, pt. I, Vol. V, Pal. N. Y., concerning which Professor Hall on p. 350 reported that "A form undistinguishable from this species occurs in the soft shales at Bedford, Cuyahoga County, Ohio."

3. Loxonema sp.-- (rr)
   This is apparently the one listed as resembling *L. delphicola* Hall by Professor Herrick. An Ohio specimen was compared with the types of this species in the New York State Museum. In general appearance and size it agrees fairly well with the original of fig. 15, pl. 28, pt. II, Vol. V, Pal. N. Y., from the Hamilton of Pompey Hill, N. Y., and also with the original of fig. 2, pl. 14, from the Hamilton of Bellona, N. Y. Some of the radiating lines (striæ) are preserved on the body whorl of the Ohio specimen which are of about the same strength as on the New York types. It is not clear, however, that the Euclid specimen has the prominent sutural band of *L. delphicola* Hall, while it is more robust than most of the New York specimens of this species, so that it does not appear safe to list it as *L. delphicola* although it may be identical with that species.

4. Bellerophon sp.--- (r)
   Perhaps the same as the one identified by Professor Herrick as *B. helena* Hall; but his figure (Geol. Surv. Ohio, Vol. VII, pl. 20, fig. 11) does not closely resemble that species. Did not find any species among the New York types that agrees with these specimens. It is not *B. helena* Hall which has a median dorsal band while the Euclid specimens are without one. The lines (striæ) on the Euclid specimens run directly across the whorl without any interruption, although they are of about the same strength as those of *B. helena*.

5. (?) Pleurotomaria sp.--- (r)
   Apparently specimens similar to the form identified by Professor Herrick as *P. sulcomarginata* Con. (see Geol. Surv. Ohio, Vol. VII, pl. 20, fig. 14); but it is not that species. Euclid specimens were also compared with types of *P. itys* Hall and *P. capillaria* Con.; but they do not appear to belong to either of these species. The revolving and radiating lines (striæ) on *P. itys* are beautifully cancellated by crossing each other, which is not shown on these specimens. The upper line of the body whorl of the

Euclid specimens is nearer a right angle like *Cyclonema hamiltoniæ* Hall; but they have heavy revolving beaded lines (striæ) like *P. sulcomarginata* Con. The slope on the upper part of the whorl of *Pleurotomaria* is more gradual than on that of these specimens.

6. Microdon sp. .... (rr)
   This specimen is probably similar to or identical with the form identified by Professor Herrick as *M. bellistriatus* Con. (Geol. Surv. Ohio, Vol. VII, pl. 20, fig. 9); but the lines (striæ) appear finer than on that species. The specimen was compared with types of *M. gregarius* Hall, *M. tenuistriatus* Hall, *M. complanatus* Hall, and *M. bellistriatus* Con. and it evidently does not belong to any one of these species. It appears similar to *M. reservatus* Hall from the Waverly of Licking County, Ohio.
7. Orthoceras sp. .... (rr)
8. (?) Orthis sp. .... (rr)
9. Orbiculoidea sp. .... (rr)
   Very small specimen.
10. (?) Goniatites sp. .... (rr)

Dr. Newberry noted that fossils were most abundant in the basal part of the Bedford shale as may be seen from the following quotation:

"The fossils are most abundant in that portion which rests immediately upon the black shale below, and here they are sometimes so numerous as to form a larger part of the mass.

"The following are some of the fossils derived from this horizon: *Syringothyris typa*, Win.; *Orthis Michelini*, Lev.; *Spiriferina solidirostris*, White; *Macrodon Hamiltoniæ*, Hall; *Hemipronites crenistria*, Phil; *Chonetes Logani*, Hall; *Lingula Cuyahoga*, Hall; *Rhynchonella Sagerana*, Win.

"In this list there are several which have peculiar interest and significance, *Syringothyris typa* and *Spiriferina solidirostris*, for example, from the fact that they are characteristic of the Lower Carboniferous rocks of other States, while *Orthis Michelini* is common to the Carboniferous all over our country and in Europe."[1]

Four years later Dr. Newberry stated that "The Bedford shale contains in some places great numbers of fossils, among which may be mentioned *Syringothyris typa*, *Spiriferina solidirostris*, *Orthis Michelini*, *Rhynchonella Sagerana*, *Chonetes Logani*, etc., all Lower Carboniferous species."[2]

Prof. C. L. Herrick studied to some extent the fossils of the Bedford shale and published a list of 17 species.[3]

Later Dr. Clinton R. Stauffer studied the fauna at the base

[1]Geol. Surv. Ohio, Vol. II, 1874, pp. 91, 92.
[2]Ibid., Vol. III, p. 23.
[3]Am. Geologist, Vol. III, 1889, p. 97, pl. 4.
Geol. Surv. Ohio, Vol. VII, pt. II, 1895, p. 507, pl. 20.

of the Bedford shale as found on Rocky Fork, near Gahanna, in central Ohio. On May 13, 1908, he wrote as follows: "This much, however, seems certain; that it is a Mississippian fauna and that it is allied to similar faunas of the Mississippi basin, Dr. Weller's Glen Park fauna for instance. That it is related to the Hamilton cannot be denied; but it is one of those recurrent faunas which comes back much changed, indeed a new fauna."

The following is the list of species from this locality as identified by Dr. Stauffer:

1. Productella cf. concentrica Hall
2. Syringothyris sp.
   Probably the one Professor Schuchert called *S. carteri* (Hall)
3. Orbiculoidea newberryi Hall
4. Rhipidomella cf. missouriensis (Swallow) Hall and Clarke
5. Nucleospira cf. minima Weller
6. Schuchertella chemungensis (Con.) Girty
7. Ambocœlia umbonata (Con.) Hall (?)
8. Lingula meeki Herrick (?)
9. Microdon cf. reservatus Hall
10. Nucula cf. glenparkensis Weller
11. Parallelodon hamiltoniæ Hall
12. Palæoneilo bedfordensis Meek
13. Bellerophon jeffersonensis Weller [1]

Immediately above the 3-inch fossiliferous layer at the base of the Bedford formation occurs a 6-inch layer of bluish-gray, argillaceous shale and above this layer on the eastern bank is 8 feet of argillaceous and arenaceous shale alternating with thin sandstones, the thickest of which is only about 6 inches, and the shale predominates.

The western bank at the fall is higher than the eastern and the following section succeeding the Cleveland shale was measured on this bank. The lower part of the Bedford dips steeply away from the creek and although somewhat difficult of access it is thought that the measurement is approximately correct. Some of the layers of sandstone show excellent examples of mud-flows and numerous ripple marks.

Section of Western Bank of Euclid Creek at the Fall.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
5.	*Euclid lentil of Bedford formation.* Top of bluff by side of railroad track. Principally layers of sandstone which are not so thick as those below	13	10	41 —	--
4.	Massive layer of bluish-gray, fine-grained sandstone	3	10	27	--

[1] While this bulletin is passing through the press the writer has read the MS. of a paper by Dr. Girty on "The Geologic Age of the Bedford Shale of Ohio," which will appear in the Annals of the New York Academy of Sciences. More than forty species and varieties are listed in this fauna which Dr. Girty states has "a distinctly Devonian facies."

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
3.	Massive, bluish-gray sandstone in upper part of zone, but the lower layers are thinner bedded, varying from 8 to 10 inches in thickness	8	10	23	2
2.	Argillaceous and arenaceous shales alternating with thin, grayish sandstones	14	4	14	4
1.	Top of *Cleveland shale*, which now forms the fall.				

The zone of shales and thin sandstones, No. 2 of the section, does not contain sandstones of sufficient thickness to be quarried and this has been excluded from the Euclid lentil. On this basis in the above section there is 26½ feet which may be referred to the Euclid lentil.

Near the northern end of the first Maxvill and Rolf quarry, not far south of this cliff, the top of the massive zone is overlain by 12⅓ feet of thinner bedded, bluish-gray sandstone. In this cliff there is 13 feet 10 inches of thinner bedded sandstone overlying the massive stratum, and although it will be shown later that farther south in the Maxvill and Rolf quarry the lower portion of these thinner sandstones becomes massive and the dip is southerly still it is thought that the top of this cliff reaches about to the top of the sandstone zone and, therefore, that the thickness of the Euclid lentil at its typical locality is not much more than 26½ feet. Dr. Newberry in his "Section on Euclid Creek" gave 20 feet for No. 3 which was described as "blue, fine-grained sandstone with oil and gas; quarried"[1] and evidently corresponds to the Euclid sandstones, which apparently favors the above delimitation of the Euclid lentil. Apparently he overlooked the 14⅓ feet of shales and thin sandstones between the base of the quarry stone and the top of the Cleveland shale, since there is no reference to it. Above the sandstone zone was given blue Bedford shale; but without stating its thickness.

The eastern wall of the northern and older part of the Maxvill and Rolf quarry, which is not far south of the above section, was partly measured.

Section of Eastern Wall of Maxvill and Rolf Quarry.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
3.	*Bedford formation.* Mainly bluish shale but with some layers of thin sandstone, the thickest perhaps 3 inches. This zone was not measured, but probably some 12 feet of shale is shown	12±	--	30½±	--

[1]Geol. Surv. Ohio, Vol. I, p. 198.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
2.	*Top of Euclid lentil.* Thinner bedded, as compared with subjacent layers, bluish-gray, fine-grained sandstone. Some of the layers of sandstone in this zone are undulating with something of a concretionary structure	12	4	18	5
1.	Massive, bluish-gray stratum of fine-grained sandstone which is 6 feet 1 inch thick. Near base of this part of the quarry as now exposed	6	1	6	1

Section of Southern Wall of the same Maxvill and Rolf Quarry.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
7.	Mainly bluish shale, but not measured.				
6.	*Top of Euclid lentil of Bedford formation.* Bluish-gray not very thick-bedded sandstone with some shale	3	8	24	--
5.	This zone is composed principally of shale, but there are some thin sandstones	3	5	20	5
4.	Heavy-bedded, massive, blue sandstone, which is *above* the 6-foot massive stratum described in the northern part of this quarry. This zone is quarried	6	9	17	--
3.	Massive stratum of bluish-gray, fine-grained sandstone, known as "bluestone" which is 7 feet in thickness. This is quarried for building stone and similar uses and is readily sawed into blocks to be used for various purposes	7	--	10	3
2.	Blue shale	--	11	3	3
1.	Blue sandstone which extends to the bottom of the quarry as now worked. A quarryman stated that altogether they worked 14 feet of solid stone at this end of the quarry	2	4	2	4

In Plate XLII, showing the upper part of this section, the top of the massive stone is evident and indicated by the lower line; the top of the Euclid lentil is shown by the upper line above which is the bluish shale.

In the southern wall of this quarry overlying the massive 7-foot stratum is 13 feet 10 inches of rock before reaching the top of the Euclid lentil and on the eastern wall of the same quarry 12 feet 4 inches overlie the 6-foot massive stratum. The interesting fact to note in this connection is the rapid thickening in that short distance of the lower portion of the overlying sandstones, so that at the southern end of the quarry there is an additional 6 feet 9 inches of massive sandstone above the massive 6- or 7-foot stratum. It is also interesting to note that the

13 feet 10 inches of rock from the top of the 7-foot stratum to the top of the Euclid lentil in the southern wall of this quarry agrees exactly in thickness with the upper part of the cliff which overlies the massive 3-foot 10-inch stratum in the section of the western bank of the creek opposite the fall.

The southern wall of the most southerly of the Maxvill and Rolf quarries, now abandoned, shows the top of the Euclid lentil not far above the water level and then the superjacent bluish-gray and reddish Bedford shale.

Section of the South Wall of the Maxvill and Rolf Southern Quarry.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Bedford shale.* Apparently some blue or gray shale in the upper part, but mainly reddish shale as exposed on the bank. Near the base mottled reddish and blue shale. There is clearly 20 feet of this shale shown on the wall of the quarry. Broken blocks of the Berea sandstone also appear, but judging from the leveled section to the ledge a short distance south of the top of the quarry wall, the base of the Berea grit must be about 10 feet higher, hence the thickness of this zone is given as 30± feet	30±	55±
2.	Bluish-gray shale principally; but containing occasional thin layers of sandstone	25½	25½
1.	Top of *Euclid sandstone*; bluish-gray sandstone which is separated from the overlying shales by a sharp lithologic break.		

Dr. Wilkinson leveled from the top of the Euclid sandstone up to the Berea ledge and obtained 56 feet. The base of the Berea, however, is not clearly shown and perhaps this 56 feet included a little of the lower Berea grit. On the quarry bank by tape measure, there is clearly shown 45½ feet of the bluish-gray and reddish Bedford shale. Dr. Newberry in his "Section of the Cliffs at East Cleveland," which is not more than 2½ miles west of this locality, gave above the blue sandstone 15 feet of blue shale and 38½ feet of red shale, making a total of 53½ feet of shale intervening between the top of the "blue sandstone" (Euclid lentil) and the base of the Berea grit,[1] which is only 2½ feet less than Dr. Wilkinson's leveled interval on Euclid Creek. It is evident that the thickness of the Bedford shale is not far from 55 feet in this region. Adding the 41 feet of the lower part of the formation to the thickness of this shale, it is found that the thickness of the Bedford formation on Euclid Creek lies between 85½ and 96 feet, and probably nearer the greater than the lesser figure. Dr. Newberry in his "Section

[1]Geol. Surv. Ohio, Vol. I, p. 197.

PLATE XLII.

Southern wall of Maxvill and Rolf quarry showing top of massive stratum, top of Euclid sandstone and superjacent bluish shale. See page 369.

of the Cliffs at East Cleveland" gave the Bedford shale as composed of 53½ feet of blue and red shale with 20 feet of subjacent blue sandstone when the top of the Cleveland shale was reached.[1] This made a total thickness of 73½ feet for the Bedford formation; but apparently Dr. Newberry overlooked the 14⅓ feet of shales and thin sandstones below the quarry stone in this region and if the thickness of this zone be added it will give nearly 98 feet for the complete thickness of the Bedford formation, which is very near the writer's maximum estimate of 96 feet for Euclid Creek.

Above the Maxvill and Rolf quarries is something of a gorge where Euclid Creek has cut through the Berea grit although it is not nearly so deep as the one farther down the stream in the Chagrin and Cleveland shales. Under the highway bridge, about one-eighth of a mile south of the Maxvill and Rolf quarries, is a fall and a little below are rather steep banks in the Berea grit. The lower half, in which small quarries have been opened on the bank of the creek, is the more massive. Above this there is much cross-bedding, with the exception of a few layers at the top of the formation which are fairly even-bedded. The structure of the formation on Euclid Creek is very similar to that of the Berea on Chippewa Creek in the vicinity of Brecksville, which will be described later. The top of the Berea, which is a coarse-grained sandstone with its upper surface very much pitted from the disintegration of nodules of iron pyrites or marcasite, forms the floor of Euclid Creek not many rods above the highway bridge.

The layers a little lower show numerous ripple-marks. Dr. Wilkinson leveled the interval from as near the bottom to the top of the Berea as it could be determined at this locality and made the thickness about 35 feet. Dr. Newberry in the cliffs at East Cleveland, about 2½ miles to the west, gave the thickness of the exposed Berea grit as 30 feet[2] so that the above measurement is not far from correct.

Before continuing with the description of the rocks shown on the upper part of Euclid Creek a section of the Malone Stone Co. quarry will be given for comparison with the sections of the Bedford formation just described on Euclid Creek or in the quarries adjacent to it. This quarry operated by the Malone Stone Co. was formerly known as the Euclid bluestone quarry and is situated about one-fourth mile west of the C. H. Burgess quarry which has already been described.

[1]Ibid., p. 197.
[2]Ibid., p. 197.

Section of the Malone Stone Co. Quarry and Ridge above it.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
19.	*Berea grit.* Coarse-grained, gray sandstone, which weathers to a buff or brownish-gray color and contains many rusty spots. The layers are more or less thin and much shattered by nearness to the surface	21	6	76	9
18.	Covered interval	15	--	55	3
17.	Bluish to bluish-gray shales alternating with thin sandstones. Some of the shales weather on the surface to a brownish color; but are apparently gray on breaking	14	--	40	3
16.	*Top of Euclid lentil of the Bedford formation.* Irregularly bedded, bluish-gray sandstone with more or less shale	2	2	26	3
15.	Layer similar to above	1	7	24	1
14.	Another similar layer and in other parts of the quarry these three layers have concretionary structure and are worthless for quarry stone	1	2	22	6
13.	Main part of quarry begins with this layer which is used commercially, although it has somewhat irregular structure	2	4	21	4
12.	Layer with similar structure to the one above	1	--	19	--
11.	Compact, bluish-gray sandstone	1	8	18	--
10.	Bluish-gray sandstone, shale parting at the base	--	10	16	4
9.	Bluish-gray sandstone	1	8	15	6
8.	Similar layer	2	2	13	10
7.	Ditto	--	5	11	8
6.	Blue argillaceous shale	--	2	11	3
5.	Blue sandstone	--	9	11	1
4.	Layer similar to above in color and bottom of quarry as worked at time of study. There are not so many courses in all parts of the quarry as have been listed above in this section and the layers are thicker	1	9	10	4
3.	Blue stone; the thickness and description of this and the two lower layers were furnished by the quarryman	1	10	8	7
2.	Hard rock with shale parting at base, from 5 to 6 feet in thickness	5	6	6	9
1.	Bluestone. (This layer is undoubtedly in the Euclid lentil, the base of which is not reached in this section)	1	3	1	3

According to the quarryman they now obtain as quarry stone about 15 feet from this quarry, which is fine-grained bluish-gray to gray sand-

stone. The stone is sawed into flagging principally; but it is also used for building stone, a use that the quarryman states is increasing. Some of the layers show excellent examples of ripple-marks, mud-flows and worm trails.

In the above section the top of the Euclid sandstone is reached with No. 16, and all of the subjacent part of the quarry with a total thickness of $26\frac{1}{4}$ feet, including No. 16, belongs in this lentil. Apparently none of the shaly zone beneath the quarry stone, which is $14\frac{1}{3}$ feet thick on the bank of Euclid Creek, is included in the above section. If this be added to the $26\frac{1}{4}$ feet of the above section which belongs in the Euclid lentil it will give a thickness of $40\frac{1}{2}$ feet for the lower portion of the Bedford formation which is in close agreement with the 41 feet obtained on Euclid Creek. It is to be noted that in the Malone Stone Co. quarry the workable part of it begins only about 5 feet below the top of the Euclid lentil while in the southern part of the Maxvill and Rolf quarry it is 7 feet below and in the older part of the quarry on the eastern wall it was $12\frac{1}{3}$ feet before the massive stratum was reached.

This sandstone is called by the quarrymen "Euclid bluestone", is so known in the trade and, as has already been shown, both Dr. Orton and Professor Cushing have used this name in describing it. This sandstone is admirably shown on Euclid Creek and in the neighboring quarries in Euclid Township and for this reason the term Euclid lentil is adopted for it. In defining the lentil the author would make its base coincide with the base of the continuous sandstones and its top where the marked lithologic change occurs between the bluish fine-grained sandstones and the superjacent blue shales. There is a shale zone below of variable thickness. As has been shown above, the thickness of the Euclid lentil in its typical locality is about $26\frac{1}{4}$ feet, while the thickness of the entire Bedford formation on Euclid Creek is about 95 feet. Apparently there is a marked difference in the thickness of the shale succeeding the Euclid lentil and forming the upper part of the Bedford formation in the Maxvill and Rolf and Malone quarries. In the former it apparently varies from $45\frac{1}{2}$ to 56 feet, while in the latter, counting all of the covered interval beneath the Berea grit as Bedford shale, there will be apparently only 29 feet of the shale. It is perhaps possible that the ledge of Berea grit has crept down the slope to some extent; but it appears to the writer that the Berea grit was deposited on an uneven surface due to former erosion and therefore that this upper shale portion of the Bedford formation varies considerably in thickness at different localities.

The description of the exposures on Euclid Creek will now be continued. A short distance above where the top of the Berea grit makes its floor, on the western side of the creek, is a bank of black shale perhaps 8 feet high. This shale is exposed occasionally on the banks of the creek, although they are all low, until the east and west highway through South Euclid

is reached, which is also the one followed by the cars of the Eastern Ohio Traction Co. for Gates Mill and Chardon. Just south of this road is a bank of soft argillaceous shale, bluish-black to blackish in color, which weathers to a bluish-gray or rusty surface, that is 20 feet or more in height. The slope of the bank is smooth, more so than that of the Chagrin shale, since there are no thin, harder layers projecting from it. From the foot of this bank to the top of the Berea grit the barometer gave only 10 feet fall, which is pretty surely an underestimate since the barometer was rising and, on following down stream, would read less than the actual fall. The topographic map indicates a fall of at least 20 feet in this distance. However, the bank above the car line and the exposures below it to the top of the Berea grit give from 30 to 40 feet of this black or bluish-black soft shale with no indications of a sandstone zone in it. It will be seen that this is rather unusual when other exposures of the black shale immediately overlying the Berea grit are studied, for generally from about 5 to 15 feet above the top of the Berea grit in the Cleveland region is found a zone of sandstone of varying thickness and massiveness. The stratigraphy of this shale overlying the Berea grit will not be carefully considered here; but later in connection with other sections in the Cuyahoga Valley it will be fully discussed. Suffice it to say that this shale belongs in the lower part of the formation which Newberry in 1870 named the Cuyahoga shale[1] and described to some extent in his "Report on the Geology of Cuyahoga County," published in 1873.[2] In 1880 Dr. I. C. White described the formations of Mercer county, Pa., which adjoins Ohio on the east, and to a similar, soft blackish shale, which is stratigraphically higher than the Berea grit, he gave the name of Orangeville shale from exposures on the Pymatuning Creek at that village on the state line.[3] Succeeding these shales occurs a mass of bluish-gray, fine-grained sandstones, lithologically something like the Euclid sandstone, which he named the Sharpsville sandstone from outcrops near the town of that name in Mercer County, western Pennsylvania.[4]

It will be shown later that the lower part of Newberry's Cuyahoga shale is largely a blackish soft shale which corresponds closely both stratigraphically and lithologically with the Orangeville shale of Dr. I. C. White. The soft black or bluish-black shale described above on Euclid Creek is referred to the Orangeville. The creek was followed until it passed beyond the limits of the Euclid quadrangle. There are occasional banks of this same soft blackish shale and the last outcrops, beyond the limits of the Euclid quadrangle, show a bluish-gray shale, perhaps some is blackish, which is still referred to the Orangeville. There are, however, occasional thin layers, ¼ of an inch or so in thick-

[1]Geol. Surv. Ohio, Rept. Prog., in 1869 (1870), pt. 1, p. 21.
[2]Geol. Surv. Ohio, Vol. I, pp. 185, 186.
[3]Second Geol. Surv. Pa., Q^3, 1880, p. 63.
[4]Ibid., p. 61.

ness, of sandstone or arenaceous shale with the bluish-gray color and texture of the Sharpsville sandstone. The shales themselves are also somewhat sandy when compared with the lower ones, showing that there is the first and gradual appearance of the lithologic conditions which characterize the Sharpsville sandstone. Up the hill 15 feet higher than the last outcrop of somewhat sandy shale just described, and near the general level of the surrounding country, are numerous loose blocks of buff to bluish-gray thin sandstones, from 1 to 2 inches in thickness. These in lithologic appearance closely resemble the lower sandstones of the terrane which succeeds the Orangeville shale in northern Ohio and which is correlated with the Sharpsville sandstone of western Pennsylvania. These abundant loose pieces of sandstone show that formerly, at least, the Sharpsville sandstone formed the surface exposures of this higher ground in Warrensville Township. The barometer gave 55 feet from the highest outcrops of the slightly sandy shale down to the base of the 20-foot cliff on the creek just south of the electric line. The topographic map indicates that this highest outcrop of shale may be some 90 feet above the base of the 20-foot bank, but it is difficult to locate the highest outcrop accurately, which would indicate that it is something like 110 feet higher than the top of the Berea grit and that there is about 125 feet of this shale before reaching the sandstones which are referred to the Sharpsville. The general direction of dip for this region is southerly, and as the shale was followed along Euclid Creek for over two miles in a southeasterly direction, this would make the above estimate of 125 feet too small for the real thickness of the shale.

As has already been shown, Euclid Creek has cut a deep gorge from the highway bridge about one-eighth of a mile south of the Maxvill and Rolf quarries to the stone bridge at Euclid, which is bordered for the greater part of the distance by steep banks composed of the Berea, Bedford, Cleveland and Chagrin formations. It is one of the best streams for the study of these formations that is readily reached from Cleveland and well worth a visit from any one interested in the scenery or geology of this region. The thickness of the exposures of the several formations shown on this creek from the stone bridge at Euclid to the highest outcrops seen is given in the following diagrammatic section. A reference to the diagram will show that rocks with an aggregate thickness of nearly 475 feet were studied on this creek which is certainly a section of no mean proportions for northern Ohio.

General Section of Formations on Euclid Creek.

Elevation	Thickness	Formation	
474′		Highest outcrops seen	
	125′+	Orangeville formation (Barometer and topographic sheet)	
349′			
	35′±	Berea grit	
314′			
	55′±	Bedford shale	Bedford formation about 96 feet
259′			
	26½′	Euclid lentil	
	14⅓′	Shales and thin sandstones	
218′			
	58′+	Cleveland shale	
160′			
	160′	Chagrin formation (Barometer)	
0′		Bed of creek at Euclid about 45 feet above Lake Erie	
	45′±	Lake Erie	

Older Formations Beneath Cleveland.—The formations which so far have been described are shown either in natural or artificial outcrops in Cleveland or its vicinity. A number of wells of considerable depth have been drilled in the city which have furnished some information regarding the still older formations which lie at some depth beneath the surface.

One of the first wells to have its record carefully tabulated was that of the Cleveland Rolling Mill Company drilled at Newburg in 1885. It was described by Dr. Orton at the meeting of the American Association for the Advancement of Science at Ann Arbor in August of that year. The record of this well as described by Dr. Orton may be represented diagrammatically as follows:

Section of Newburg Well Compiled from Dr. Orton's Description.

Depth.	Thickness	Description	Formation
	40′	Drift	
40′	1310′	Shales changing in color from light to dark with frequent alternations	Cleveland, Erie, Huron
1350′	310′	Solid limestone. Corniferous limestone, at least its upper part	
1660′	40′	Sandstone sharp and clear. "May be Oriskany"	
1700′	290′	Limestone	
1990′	164′	Rock salt and thin bands of shale	Medina (?)
2154′	15′	Gypsum[1] and shale	
2169′	81′	Limestone	
2250′	50′	Rock salt	
2300′	40′	Gypsum,[1] bluish	
2340′	20′	Sandstone	
2360′	18′	Shale	Hudson River(?)
2378′	22′	Limestone	
2400′	20′	Rock salt	
2420′	10′	Shale	
2430′	40′	Limestone	
2470′	5′	Rock salt	Utica (?)
2475′	8′	Shale	
2483′	167′	Limestone	
2650′	300′±	Hard limestone with petroleum in small amount	Trenton limestone
2950′		Bottom of well at time of report, but drilling had not ceased	

Dr. Orton stated that he did not offer a final interpretation of the above record; but he thought the 40-foot sandstone reached at a depth

[1]Professor Cushing has stated that each bed of rock salt is underlaid by anhydrite rather than gypsum, as given in Dr. Orton's desciption.

of 1,660 feet might be the Oriskany. The rock salt from 2,000 feet downwards he stated "comes more nearly into range with the Medina, Hudson River and Utica groups than with the Salina, to which it would most likely be referred at first sight." While the oil-bearing limestone struck at a depth of 2,656 feet[1] and which continued without interruption to the bottom of the well as then reported was identified as "the Trenton limestone, if we can rely upon the evidence of its petroliferous quality by which it is connected with the new wells of northwestern Ohio."[2]

Dr. Orton reconsidered the record of this well in 1888 and changed decidedly from his former views regarding the correlation of the deposits from the limestone downward. He stated that the well was drilled to a depth of a little more than 3,000 feet and the last drillings were apparently from a red limestone which was identified as Clinton. The 40-foot sandstone was compared with the Sylvania sandstone of Lucas County which Dr. Orton had shown does not occur at the Oriskany horizon, but "is buried under 150 or 200 feet of the Lower Helderberg limestone."[3] Dr. Orton also provisionally referred a sandstone found at a depth of 1,300 feet in a well drilled at the corner of Euclid and Case Avenues to the Sylvania.[4]

The portion of the Newburg well record below the bottom of the 1,310 feet of Devonian shale was correlated in the following manner by Dr. Orton, although it does not appear that he made the thickness of the divisions correspond exactly with the record of the well.

100′	Upper Helderberg limestone
500′	Lower Helderberg limestone
800′	Salina group
300′	Niagara limestone Clinton limestone.[5]

The thick sandstone reached at 1,660 feet was also correlated with the Sylvania sandstone by Peter Neff in 1890, although he gave its horizon as "in the Niagara series."[6] He described four wells in the

[1]In the description of the well section, Dr. Orton gave the depth as 2,656 feet, but the total thickness of all the overlying intervals from the top of the hard limestone which he called Trenton to the mouth of the well, as given in his section, amounts to only 2,650 feet. It appears probably that 2,650 feet is the correct depth instead of 2,656 feet.

[2]Proc. Am. Assoc. Adv. Sci., Vol. 34, 1886, p. 221.

[3]Geol. Surv. Ohio, Vol. VI, p. 352.

[4]Ibid., p. 430.

[5]Ibid., p. 356.

[6]Bull. Geol. Soc. America, Vol. I, p. 32.

vicinity of Cleveland, including the one at Newburg, in which the Sylvania sandstone was reached

In the light of our present knowledge it appears that the correlation of the deposits in the Newburg well below the top of the limestones may be modified somewhat. The Upper Helderberg limestone is now called the Onondaga limestone by the New York Geological Survey. Between Cleveland and the Sandusky region there are no outcrops of the Devonian limestone, but at Sandusky there is about 110 feet[1] of the Columbus limestone which is regarded as the Ohio equivalent of the Onondaga limestone. Superjacent to the Columbus limestone, however, is the Delaware with a thickness of from 40 to 50 feet and it is not improbable that some of this limestone is represented in the upper part of the limestones reached in the Newburg well. To the northeast of Cleveland at Buffalo where the Onondaga limestone outcrops, it has, according to Professor Bishop, a thickness of 108 feet,[2] which is essentially the same as that assigned by Dr. Orton to the Upper Helderberg limestone in the Newburg well. The Sylvania sandstone in its typical region in Lucas County occurs some distance below the top of what was called the Lower Helderberg or Waterlime formation in the Ohio reports. In 1893 Dr. Lane of the Michigan Survey named similar deposits in that state the Monroe formation apparently from the county of that name which adjoins Lucas County on the north and this name has been adopted by the Ohio Survey.[3] The Lower Helderberg limestone occurs typically in the Helderberg Mountains of eastern New York; but it has entirely disappeared before Buffalo is reached at the eastern end of Lake Erie. It is not probable that any rocks of the age of the Lower Helderberg limestones occur in Ohio and it is probable that the two divisions referred to this limestone and the Salina group in Dr. Orton's account of the Newburg well are both to be correlated with the Salina beds of New York. The writer has recently stated very briefly the evidence supporting this conclusion.[4] The limestone reached at a depth of 2,650 feet is probably the top of the Guelph of the Niagaran series as stated by Dr. Orton, which presumably corresponds in a general way with the Cedarville limestone of southwestern Ohio; or in case the Guelph is absent in northeastern Ohio then it probably represents the Lockport limestone of New York.

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[1]For a recent paper by Dr. Charles K. Swartz giving sections of the Devonian limestones in the vicinity of Sandusky together with their thickness, see The Johns Hopkins University Circular, N. S. 1907, No. 7, pp. 56-65. For a still later account see the book by Dr. Clinton R. Stauffer, Bull. 10, Fourth Ser., Geol. Surv. Ohio, 1909, pp. 124-132.

[2]Fifteenth Ann. Rept. State Geol. [N. Y.], 1898, p. 390. In this report what is now called the Onondaga is given under the heading of "Corniferous and Onondaga Limestone," the "bull-head" is the Cobleskill and the subjacent Water-lime is the Bertie water-lime which is the upper member of the Salina beds.

[3]For a recent consideration of the term "Monroe formation" and its subdivisions, see the Bull. Geol. Soc. America, Vol. XIX, 1909, pp. 553-556.

[4]Geol. Surv. Ohio, Fourth Ser., Bull. 7, 1905, pp. 25-28.

For the purpose of comparison with the above records an account of some of the later deep wells in Cleveland will be of interest. Mr. D. F. Wallace of the United Salt Company kindly allowed the writer to make a copy of the company's log of their well No. 4, drilled in 1893, the mouth of which is about 400 yards east of their plant by the Lake Shore Railroad at the foot of Madison Avenue. According to the barometer the mouth of the well is about 55 feet above the level of Lake Erie. The company's log of this well is as follows:

United Salt Co. Well No. 4.

No.	Driller's description of strata.	Thickness. Feet.	Total depth Feet.
1.	Sand	15	15
2.	Quick sand	6	21
3.	Blue clay	129	150
4.	Sand and clay	9	159
5.	Quick sand	76	235
6.	Fine gravel	6	241
7.	Gravel cemented with hard clay	26	267
8.	Soft slate	24	291
9.	Medium hard slate	15	306
10.	Soft slate	5	311
11.	Soft slate mixed with gravel	7	318
12.	Hard black slate	54	372
13.	Soft slate	12	384
14.	Light colored slate	20	404
15.	Black slate	20	424
16.	Soft slate	29	453
17.	Black slate	74	527
18.	Light colored slate	21	548
19.	Black sand rock	96	644
20.	Red slate (Mr. Wallace thinks the color of this may have been brown)	70	714
21.	Light colored slate	131	845
22.	Dark colored slate	145	990
23.	Lime rock	390	1380
24.	White sandstone	33	1413
25.	Lime rock	11	1424
26.	White sandstone	16	1440
27.	Lime rock	315	1755
28.	Lime rock and salt	10	1765
29. to 37.	Then follows five layers of rock salt alternating with "lime rock" of driller. The total thickness of these five beds of salt is 170 feet	213	1978
38.	Slate	16	1994

The total depth of this well as measured with a steel line is 2,006½ feet. A condensed copy of this log, with the exception of the lower portion which is given in detail, has been published by Professor Bownocker.[1] The first Paleozoic rocks reached in this well belong in the Chagrin formation and it is interesting to note the alternation of light and dark colored shales throughout the lower 672 feet of the Devonian shales. The lowest 145 feet of the shale, however, is given as "dark

[1]Am. Geologist, Vol. XXXV, pp. 372, 373.

colored slate," which apparently indicates that the very light colored Olentangy shale, which lies between the Ohio shale and Delaware limestone in central Ohio, has either entirely changed its lithologic character or is wanting. The top of the Devonian limestone was reached at a depth of 990 feet and the white sandstone, 33 feet thick, reached at a depth of 1,380 feet is probably the same as that correlated with the Sylvania sandstone in the wells previously reported. The thickness of the interval from the top of the Devonian limestone to the top of the sandstone is reported as follows from these wells: Newburg, 310 feet (Orton); Jewett farm, 1¼ miles south of Newburg well, 364 feet (Neff); Euclid well, about ½ mile from shore of Lake Erie and 13 miles northeast of Newburg well, 372 feet; and well No. 4 at foot of Madison Avenue, 390 feet. An interesting thing in the log of the last well is that after passing through the 33 feet of sandstone and 11 feet of "lime rock" another stratum of white sandstone 16 feet in thickness was penetrated. For that member of the Monroe formation succeeding the Sylvania sandstone and forming its upper part in northwestern Ohio, the writer has proposed the name Lucas limestone,[1] which may be advantageously used in describing the Cleveland well records. Later on account of the rock being a calcium magnesium carbonate it has been called the Lucas dolomite.[2] The well did not reach the top of the Niagaran series and below the base of the Devonian limestone it may probably all be correlated with the Salina beds of New York. A condensed diagrammatic section of the well showing the general age of the formations penetrated by it would be about as follows:

Condensed Record of Well No. 4.

Depth	Thickness	Formation	
		Mouth of well	
267′	267′	Alluvial and drift deposits	
990′	723′	Chagrin and (?) Huron shales	
1380′	390′	Devonian and Lucas limestones	Probably represents the Monroe formation including Salina beds of New York
1413′	33′	Sylvania sandstone	
2006½′	593½′		
		Bottom of well	

[1] Jour. Geology, Vol. XI, 1903, pp. 521,540.
[2] Bull. Geol. Soc. America, Vol. XIX, 1907, p. 556 and also see pp. 541, 549.

The log of well No. 5 of the United Salt Company, the mouth of which is located about 300 yards south of the office, was also copied. The condensed log of this well is as follows:

Condensed Record of Well No. 5.

Depth	Thickness	Formation
		Mouth of well
	225½′	Alluvial and drift deposits
225½′		
	629½′	Chagrin and (?) Huron shales
855′		
	1121′	Devonian limestone Monroe formation including Salina beds
1976′		Bottom of well

The Sylvania sandstone was not noted in this log; but 490 feet below the top of the Devonian limestone a "soft sand," 23 feet in thickness, was recorded. This is probably the equivalent of a sandstone which has been noted in a number of wells at some distance below the Sylvania. As for example, Dr. Orton noted another sandstone 70 feet below the top of the Sylvania in the well drilled at the corner of Euclid and Case avenues.[1] In the lower part of this well five strata of rock salt were also penetrated with a total thickness of 145 feet.

A well was drilled at the corner of Second and Central avenues, which is by the barometer from 75 to 80 feet higher than the railroad tracks at the Lake Shore Station. The record down to 1,230 feet is from the driller's log, but below that samples were saved at about 10 feet apart which have been hastily examined by the writer. The samples were carefully washed and dried when they were saved so that they are not stained and they constitute an interesting and valuable record of the deeper third of this well.

Well at Corner of Second and Central Avenues.

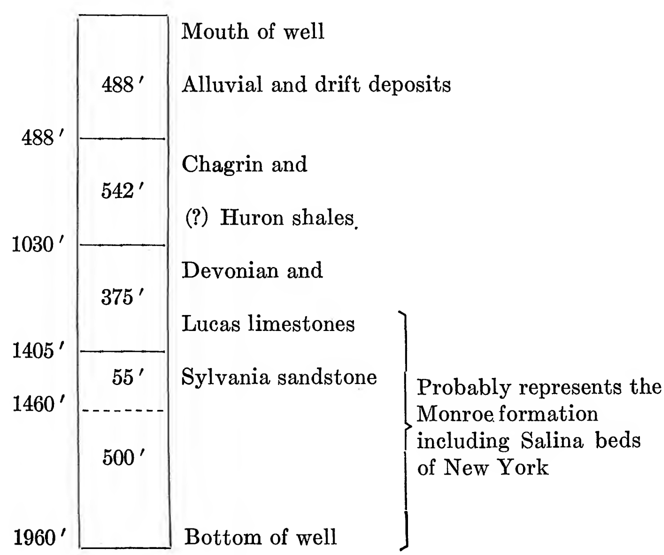
No.	Description of sample.	Thickness. Feet.	Total depth. Feet.
1.	First gravel	481	481
2.	Clay	7	488
3.	Rock	30	518
4.	White shale	182	700
5.	Black shale	330	1030
6.	Black lime	50	1080

[1]Geol. Surv. Ohio, Vol. VI, p. 430.

No.	Description of sample.	Thickness. Feet.	Total Depth. Feet.
7.	Brown lime. The above entries are from the driller's log, which is not very accurate regarding the lithology	150	1230
8.	First sample, saved at a depth of 1230 feet, which consists of light-gray chips with a few dark gray to blackish ones. The samples to a depth of 1340 feet consist mainly of light or dark gray to brownish chips	110	1340
9.	More than one-half the chips are decidedly brownish-gray, similar to surface exposures of the Monroe. The other chips are of light gray color	20	1360
10.	Light-gray chips predominate	40	1400
11.	Slightly darker colored, very compact limestone	5	1405
12.	Sample composed almost entirely of grains of white glassy, quartz sand. No effervescence in cold HCl	5	1410
13.	Finer grains of pure white quartz sand, with an occasional one that effervesces in cold HCl	20	1430
14.	Clear fine white grains of quartz, slightly stained by rust, and those from the lower 10 feet are slightly coarser	20	1450
15.	Clear white quartz sand. Some chips of very dark gray rock, but no effervescence in cold HCl	10	1460
16.	Part of sample white quartz sand; but the greater part is composed of brownish-gray chips with slight effervescence in slightly heated HCl	10	1470
17.	Sample composed of clear white quartz sand	10	1480
18.	Some white quartz sand; but more brownish-gray chips which effervesce slowly in warm HCl	20	1500
19.	Mainly fine brownish-gray chips of limestone	10	1510
20.	Ditto, with strong effervescence in cold HCl	40	1550
21.	Fine brownish-gray limestone, strong effervescence in cold HCl	40	1590
22.	Light brownish-gray chips of compact limestone; strong effervescence in cold HCl	50	1640
23.	Brownish-gray, compact limestone which effervesces more slowly in cold HCl	30	1670
24.	Fine chips of brownish-gray, very compact limestone which effervesces somewhat slowly at first, but increases on standing	30	1700
25.	Dark brownish-gray and coarser chips which effervesce slowly in cold HCl	70	1770
26.	Lighter gray in color but chips about the same as above, except that in the lower 20 feet they are finer	30	1800
27.	Mixed dark and lighter gray chips with very slight effervescence in cold HCl	20	1820
28.	Brownish-gray chips, very compact rock which scarcely effervesces in cold HCl, but rather strongly on heating	2	1822
29.	Top of rock salt which alternates with "rock" of driller's record to a depth of 1952 feet. Four strata of salt are reported with a total thickness of 97 feet	130	1952
30.	Light-gray compact chips which effervesce on heating the HCl but only slightly in cold HCl	8	1960
	Bottom of well.		

In general the above record agrees closely with that of the other wells reported in Cleveland. The top of the Devonian limestone was reached at a depth of 1,030 feet, which is 40 feet deeper than in well No. 4 of the United Salt Company, but its altitude is undoubtedly fully that amount higher. The top of the Sylvania sandstone was reached at a depth of 1,405 feet, 375 feet below the top of the Devonian limestone. It will be remembered that this interval in the Newburg well is 310 feet, the Jewett farm well 364 feet, the Madison Avenue well 390 feet and the Euclid well 372 feet, so that it corresponds well with the depth in the majority of these wells. The interesting feature of this well is the great thickness of this sandstone which for 55 feet is composed almost entirely of grains of glassy quartz sand. Below this is 10 feet composed partly of limestone followed by 10 feet of clear white quartz sand, below which is 20 feet containing some sand, but the greater percentage is brownish-gray limestone. This record shows, therefore, 55 feet of clear sandstone below which is 40 feet that is composed in part of sand, but to a greater extent of limestone. In the Newburg well 40 feet of sandstone was reported while the log of the Madison Avenue well gave 33 feet of white sandstone followed by 11 feet of limestone, below which was 16 feet of white sandstone. If all of the sandstone and sandy strata be grouped together in these wells it will give 40 feet for the Newburg, 60 feet for the Madison Avenue and 95 feet for the one at the corner of Second and Central avenues. The strata below the Sylvania sandstone in the last mentioned well belong in the Monroe formation and may be correlated with a part of the Salina beds of New York. A condensed diagrammatic record of this well follows:

Condensed Record of Well at Corner of Second and Central Avenues.



Skinner's Run Sections.—After this rather lengthy digression, for the purpose of describing the excellent outcrops on Doan Brook in Cleveland and Euclid Creek to the east, together with some account of the older formations beneath the city as revealed by various well records, the description of the formations as shown on the Cuyahoga River and its tributaries to the south of Cleveland will be resumed. Willow is a station on the Baltimore and Ohio railroad in the northeastern part of Independence Township. About one-half mile north of this station Skinner's Run enters the Cuyahoga River from the west after crossing the northern part of Independence Township. The head waters of the stream are near Walling Corners in the northeastern corner of Royalton Township and it then flows in a general northerly direction nearly across the eastern part of Parma Township until it turns easterly across Independence Township to the river. A considerable part of its course is bordered by fairly steep banks which afford good opportunities for studying the formations shown along the stream. The exposures of the higher formations along its upper course were shown to better advantage in the summer of 1910 along Broadview Avenue which was being graded and paved. This avenue runs nearly parallel with the stream from Walling Corners until crossing it in the northeastern corner of Parma Township.

The banks along the lowest part of the stream are alluvial; but outcrops of Chagrin shale are reached before following it very far above the road leading from Willow to Brooklyn. This lowest outcrop is some 5 feet lower than the railroad track at Willow and the rocks consist of bluish argillaceous shale with layers of arenaceous shale to thin sandstones. Some of the thin layers are rather dark gray shale and much of it weathers to an olive color.

Forty-five feet higher (in general the elevations were determined by the barometer) there is a small but sharp anticlinal fold on the southeast bank of the run where the following section is shown:

No.		Thickness.		Total thickness.	
		Ft.	In.	Ft.	In.
4.	Gray sandstone making a small fall in the stream	--	7½	3	3½
3.	Argillaceous shale	--	6	2	8
2.	Sandstone layer	--	2	2	2
1.	Arenaceous shale	2	--	2	--

Thirty feet higher the foot of the first bank capped by Cleveland shale was reached. This bank is on the southeastern side of the stream and a little above a tributary entering from that side. The section of this bank is as follows:

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Cleveland shale.* Upper part of bank composed of coarser layers with an estimated thickness of 10 feet	10±	68
2.	Black, slaty shale with an estimated thickness of 30 feet or more	30±	58
1.	*Chagrin formation.* Composed mainly of bluish, argillaceous shale with thin layers or lenses of rusty colored, somewhat calcareous material. Twenty-eight feet as leveled by Mr. Miller	28	28

These sections indicate that the upper 103 feet of the Chagrin formation, determined largely by the barometer, is shown on the banks along the lower course of this stream.

Farther up the run the contact of the gray and black shale is shown in the bed of the stream. Still farther up the stream is a high cliff on the northwest side composed mainly of black shale, the lower part of which is very black and tough like typical Cleveland shale. Higher there are zones that are not so hard, in fact that are rather soft on the weathered surfaces and light colored, some of them perhaps as light colored as the shales of the Chagrin. These softer and lighter colored zones are lithologically similar to zones that appear in the black shale in the sections to the east of Cleveland. There are also layers of arenaceous shale of blue to bluish-gray color which lithologically resemble certain ones of the Chagrin and might easily be taken for them. The softer bands of shale, which are lighter colored on the surface, on breaking are generally black, especially when deep enough in the bank to be beyond the effects of thorough weathering. The softer shale is perhaps not so tough and gritty as the typical slaty Cleveland shale. It is generally believed that this lower black shale west of Cleveland represents a downward encroachment of the conditions of black shale deposition upon the upper portion of the Chagrin formation as it occurs in the immediate vicinity of Cleveland. It might be stated, however, that bands of softer shale weathering to a lighter color occur in the midst of these typical black shales. An example of such softer shale in a well weathered bank is to be seen in the lower bank of the Sunbury shale in the Lithopolis glen in central Ohio.

The highest layer of thin bluish-gray sandstone noted in going up the run is 35 feet higher (barometer) than the base of the black shale. The bank above appears to be composed entirely of black shale until a concretionary sandstone zone is reached. This statement probably ought to be modified somewhat in reference to the apparent upward extent of black shale as shown farther up the stream where the rock was examined at close range. In the bed of the run a few rods below the railroad fill and opposite the cliff on the southern side are layers of bluish to bluish-gray shale, part of which are argillaceous and the re-

mainder arenaceous, that occur in the upper part of this black shale zone. There are also somewhat concretionary, irregular layers which have very compact structure and are probably somewhat calcareous; while small concretions of this texture also occur at various places in these upper shales without being at any definite horizons. Also the lower sandstone zone to be described on the southern bank at this locality does not appear so prominently farther down the run, so that the black shale appears to continue without much break to the more conspicuous concretionary sandstone higher on the bank.

The section for this portion of the run is about as follows, all of which the writer would refer to the Cleveland shale:

No.		Thickness. Feet.	Total thickness. Feet.
2.	Probable top of *Cleveland shale*. Zone composed almost entirely of black, slaty shale; but with some layers of blue to bluish-gray, argillaceous and arenaceous shale, particularly in upper portion	$25\frac{1}{2}$	$60\frac{1}{2}$
1.	Layer of thin, bluish-gray sandstone at top of zone. Below is black shale which contains bands of light colored, soft shale and thin layers of bluish-gray sandstone. Lowest part of zone consists of very black, tough shale which rests on the bluish, argillaceous shale of the Chagrin	35	35

At the upper end of the cliff on the southern bank, which is only a short distance below the railroad fill, the following section occurs above the zone of nearly all black shale:

No.		Thickness. Ft.	In.	Total thickness. Feet.
4.	Bluish, fine-grained sandstone with more or less contorted or concretionary structure	6	7±	$23\frac{1}{2}$ —
3.	Black, fissile shale of usual character as shown on weathered bank. The lower part of the zone is composed of blackish, arenaceous shale	14	6	$16\frac{5}{6}$
2.	Bluish-gray, thin-bedded, rather fine-grained sandstone, which in the lower part contains considerable marcasite. Part of this sandstone in a comparatively short distance may change to an arenaceous shale, and on the banks farther down the run it does not appear to be so well marked an horizon	2	4	$2\frac{1}{3}$
1.	Mainly black, rather slaty shale, but with an occasional bluish to bluish-gray layer near stream level. There is also an occasional concretionary lens of blue, fine-grained sandstone in the upper part of this zone as, for example, a few rods below where the above section was meas-			

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
	ured is one from $1\frac{3}{4}$ inches to 4 inches thick, which is $14\frac{1}{4}$ inches below the base of the lower sandstone and extends for a short distance along the bank. These shales are in the upper part of the zone of nearly clear black shale with a thickness of $25\frac{1}{2}$ feet.				

The upper sandstone, zone No. 4, of the above section, when studied at different parts of the cliff, has the appearance of more or less large concretionary masses which do not occur at precisely the same stratigraphic horizon. This is clearly shown by two measurements on the bank farther down stream than the one just given as well as by the section on the opposite side of the run, a short distance above the railroad fill. The cliff a few rods below the section just given furnished the following one:

No.		Thickness. Ft.	In.	Total thickness. Feet.
3.	Concretionary sandstone mass	9	10	$26\frac{1}{3}$
2.	Mainly black, fissile shale; but with some small lenticular concretions at various horizons	14	2	$16\frac{1}{2}$
1.	Lower sandstone zone	2	4±	$2\frac{1}{3}$

A few rods farther down the stream on the same bank the section is as follows:

No.		Thickness. Feet.	Total thickness. Feet.
3.	Concretionary sandstone mass	--	--
2.	Mainly black, fissile shale with some small lenticular concretions and farther down the bank oblique sandstone dykes (?)	24	$26\frac{1}{3}$
1.	Lower sandstone zone	$2\frac{1}{3}$±	$2\frac{1}{3}$

The last two sections, which are only a few rods apart, show very clearly the difference in horizons at which the concretionary sandstone, No. 3, occurs, since there is an increase of 9 feet 10 inches in the thickness of the shale interval between the two sandstones. The lower sandstone zone on the northern bank above the railroad fill shows a good deal of variation. Not far above the lower end of the bank there is about 10 inches of thin-bedded, bluish-gray sandstone apparently representing the lower part of the zone as shown below the fill. Above is black bituminous to arenaceous shale; but with the top of the zone fairly well marked by a sandstone layer. Along part of the bank, two feet above the 10-inch sandstone, is a concretionary one from 3 to

6 inches thick. On this bank the upper sandstone zone has been largely replaced by shale, although there are more or less conspicuous concretionary masses of sandstone.

At the upper end of this cliff, a few rods farther up the run, the following section was measured:

No.		Thickness. Ft.	In.	Total thickness. Feet.
6.	Black shale with concretionary sandstone at base of zone; but sandstone not very thick	3	--	31⅔
5.	Apparently all black, fissile shale	21	--	28⅔
4.	Top of sandstone zone which consists of thin-bedded, bluish-gray sandstone	--	9½	7⅔
3.	Bluish-gray, arenaceous shale to thin-bedded, blue sandstone and even black shale, particularly a little farther down the run	1	7½	6⅚+
2.	Base of sandstone zone which consists of thin-bedded, bluish-gray sandstone	1	3	5¼
1.	*Cleveland shale.* Black, fissile shale to level of Skinner's Run	4	--	4

In the above section, zones Nos. 2 to 4 inclusive, with a thickness of 3 feet 8 inches, which in one place is about 4 feet, are regarded as representing the lower sandstone zone on the bank below the railroad fill, where it is 2 feet 3 inches in thickness. On the next bank, a few rods farther up stream and on the southern side, the lower sandstone zone has become very concretionary; while in the upper part of the bank is a conspicuous concretionary sandstone, corresponding in a general way to the upper one described on the bank below the railroad fill.

In places the black shales between these sandstones are considerably deformed, showing both folding and faulting. They also contain more or less vertical deposits of sandstone and marcasite which apparently filled cracks in the shale, considerably resembling dykes of igneous rock which may perhaps be called sandstone dykes. They vary in thickness from less than one-half inch up to an inch, and some little distance above the railroad fill is one composed mostly of sandstone, bluish in color, which is $3\frac{1}{2} \pm$ inches in width.

Farther up the stream, on the southern bank, and not far below the Broadview Road bridge, is a conspicuous concretionary sandstone which begins in the bed of the run and its upper part continues obliquely up the bank to the west while its lower part is replaced by black shale. The lower part of this concretionary mass is mostly bluish, compact sandstone; but some of it is calcareous and very hard. It is 25 feet across the base of this concretionary mass and the barometer gave it as only 5 feet higher than the base of the lower sandstone on the first cliff above the railroad fill.

The highest black shale seen on the run is at the top of the bank just above the Broadview Road and below the house of John Pritsch. From the top of this black shale down to the stream level at the time of the measurement was 9 feet 4 inches. A few rods up the run part of this black shale is replaced by concretionary masses of sandstone which, however, do not extend to quite so high an horizon as the black shale. This sandstone is clearly of concretionary structure since a short distance down the stream near the bridge its horizon is clearly occupied by black shale. Nearer the bridge than the upper sandstone is a lower one which runs down obliquely in the black shale to near water level a few yards above the upper end of the bridge. A view of this bank is shown in Plate XLIII, in which Mr. Miller is standing on the lower concretionary zone, while the upper sandstone is shown farther up the stream ending near the lower end of the retaining wall. A few yards above in the bed of the run opposite the retaining wall directly below the Pritsch house is a large mass of sandstone.

The barometer gave the top of this outcrop above the Broadview Road bridge as only 20 feet higher than the base of the lower sandstone on the bank below the railroad fill. If that be correct then the first bank above the railroad fill gives the thickest section of this upper black shale and concretionary sandstone where it is $27\frac{2}{3}$ feet from the base of the lower sandstone to the top of the black shale as shown on the cliff.

There is some uncertainty as to whether these upper $27\frac{2}{3}$ feet of black shales and sandstones should be referred to the Cleveland shale or the Bedford formation. It is true that the shales lithologically closely resemble those of the Cleveland; but on the other hand the sandstones are more or less similar to those of the Bedford. No fossils have been found in these deposits; but it is believed that the black shale conditions continued after the beginning of Bedford time and partly replaced the usual lithologic deposits of that formation. This conclusion is supported by the transition from the Cleveland shale to the Bedford formation on East Branch below Berea, a section that is described in a following chapter of this bulletin and where the Bedford fauna occurs in somewhat calcareous layers *below* the top of the black shale. For the above reasons these $27\frac{2}{3}$ feet of black shales and concretionary sandstones are referred, at least provisionally, to the Bedford formation.

This leaves $60\frac{1}{2}$ feet of mostly black shale which is called Cleveland, although it is probable that the lower part represents what is called upper Chagrin shale in the sections farther east; to which possibly may be added the $27\frac{2}{3}$ feet of transitional deposits, which would make a total of $88\frac{1}{6}$ feet. The former figure, however, is in closer agreement with the thickness of the Cleveland shale in Cleveland where it will be recalled that on Mill Creek at Newburg, only 4 miles to the northeast, it is but 45 feet thick and on Doan Brook, nearly 9 miles northeast, $51\frac{3}{4}$ feet thick, the lower part including bands of grayish shale.

PLATE XLIII.

Upper zone of black shale and concretionary sandstone of Bedford formation (?) on Skinner's Run.

Above the John Pritsch house and Broadview Road the stream cuts through the remaining part of the Bedford formation and the entire thickness of the Berea grit, the top of the latter formation being reached in the bed of the run some distance above the first east and west road crossing the stream, while farther up the run are banks of the Orangeville formation.

Section of the Orangeville, Berea and Bedford Formations on Skinner's Run.

No.		Thickness. Feet.	Total thickness. Feet.
6.	*Brecksville shale.*[1] The highest outcrop examined on the bank of the run occurs a little above a private road which crosses it about one-half mile above the east and west road. The top of this shale bank is 40 feet higher, according to the barometer, than the top of the Berea sandstone. Farther down the stream are other banks of shale, and one of them was estimated to be 35 feet high. The shale in the lower part of this cliff is very black, with the lithologic character of the Sunbury; but higher it changes gradually to a bluish-black color, although part of it is almost black. Some of the shale is a little gritty; but it is mainly soft and argillaceous. On this bank there is no sandstone zone separating the Sunbury from the Brecksville shale	40±	190½
5.	*Berea sandstone.* The top of the formation is shown in the bed of the run some distance above the bridge on the east and west road. The top of the upper layer is very much pitted, due to the disintegration of iron pyrite and marcasite, and its washing out of the stone. The formation is well shown below the viaduct where its entire thickness is exposed on the bank. The same thickness, 55 feet, was obtained by the barometer from its base to its top, on the bank, as from its base when followed up the run to its top layer. The cliff of Berea below the bridge is capped by black, fissile shale at the base of the Orangeville formation. In the upper part of the Berea are some zones of bluish shale, with shaly sandstone 2± feet in thickness. The upper and greater part of the formation is composed mainly of thin-bedded sandstones, which are more or less cross-bedded in structure. The lower 10 feet or so, especially where the base is lowest, is massive. At the lower end of the gorge, 7½ feet of thin-bedded sandstone is shown in a small run on the eastern side of the stream, above the cliff. Where the Berea runs downward to the lowest extent there is a vertical cliff of it 33 feet high, so that 40½ feet of Berea sandstone is shown at this locality. The upper part of the cliff consists of thin-bedded sandstone. The lower part, when weathered, contains numerous brown spots, and the lower portion of the basal course of this part of the cliff contains a large		

[1]This shale is named on p. 449 of this bulletin.

No.		Thickness. Feet.	Total thickness. Feet.
	amount of marcasite. The lowest part is massive, coarse-grained, quartz sandstone, containing marcasite. The line of contact with the Bedford is very irregular, showing a marked disconformity which is more fully described in the text following this section. The contact between the Berea and Bedford at the northern end of this cliff is shown in Plate No. XLIV, where the chocolate colored shale forms the lower and smooth part of the bank	55	150½
4.	*Bedford formation.* At the top of the Bedford, under the lowest part of the Berea sandstone, there are 2¼ feet of soft, gray, argillaceous shale. Most of the zone, however, is composed of soft, argillaceous, chocolate colored shale. The thickness of this zone varies from 45 feet where the base of the Berea sandstone is lowest, to 55½ feet where it is highest. This variation of 10½ feet in the vertical position of the base of the Berea sandstone occurs in a horizontal distance of 90 feet. The highest part of the basal line of the Berea sandstone is at the northern end of the cliff	55½±	95½
3.	Gradual change from bluish to chocolate colored shales, the lower of which are bluish and argillaceous. At the base a zone of thin, bluish-gray sandstones, some of which are ripple-marked. Above this zone, on the John Pritsch farm, are 20 feet of chocolate shale	10	40
2.	Covered zone down to top of black shale and concretionary sandstones above bridge on the Broadview Road	10	30
1.	The top of the outcrop of black shale at the Broadview Bridge, according to the barometer, is 20 feet higher than the base of the lower sandstone, which is provisionally taken for the base of the Bedford formation, as exposed on the cliff below the railroad fill. Apparently some of the covered zone given above is represented by the upper part of the bank on the cliff above the railroad fill	20	20

In the above section the thickness of the Bedford formation is given provisionally as 95½ feet. It has already been stated that there may be a question as to whether the lower 27⅔ feet should be referred to the Bedford or the Cleveland; but it appears to the writer that the evidence favors its reference to the former formation. If this portion were put in the Cleveland shale then there would be left only about 12⅓ feet to represent the blue shale and sandstone in the lower part of the Bedford formation; while on Big Creek, only about 3½ miles to the northwest, the corresponding part of the Bedford is 41 feet thick. It is also to be noted that 101 feet was obtained for the entire thickness of the Bedford on Big Creek, which does not differ markedly from the 95½ feet assigned to this formation on Skinner's Run. Again on Big Creek 60 feet of chocolate colored shale was obtained, which perhaps

PLATE XLIV.

Disconformity between Bedford and Berea formations on Skinner's Run. Lower bank.

indicates that not quite so much of the upper shale of the Bedford had been removed by erosion.

In the upper part of the gorge a thickness of 55 feet was obtained by the barometer for the Berea sandstone and the same thickness when followed up the run from this locality to the highest outcrop of the sandstone in the bed of the stream.

The evidence of disconformity between the Berea and Bedford formations is excellently shown on the banks of this stream. A fine example of an eroded upper surface of the Bedford shale is shown at the northern end of the gorge where, on ascending the stream, the first cliff of the Berea sandstone is found. At this locality the base of the Berea rises 10½ feet in a horizontal distance of 90 feet as was stated in the description of the section. Plate XLIV shows the northern end of this cliff, with the base of the Berea sandstone rising toward the north, below which is the smooth bank of Bedford chocolate shale.

Farther up the run is another bank on the eastern side of the stream where the irregular line of contact between the two formations is finely shown. At this locality there are 9 feet 8 inches of Bedford shale where the Berea is lowest and 19 feet 9 inches of Bedford shale at the point where the base of the Berea is highest which gives a rise of 10 feet 1 inch in a horizontal distance of 31 feet. This contact is shown in Plate XLV, A, and along four of the planes shown in it the line is as sharp as though faulted. There are oblique joints along some of the oblique contact faces; but it does not appear that there has been faulting. The most of the Bedford on the bank is of chocolate color with a zone of bluish-gray soft argillaceous shale at the top which varies in thickness; but may be called 3 ± feet. On this or the middle cliff where the Berea sandstone is lowest the blue shale is lower than the top of the chocolate shale where the base of the Berea is highest. Where the base of the Berea is lowest, the lower 10 feet or so of it is massive, above which the layers are thin with more or less cross-bedding; but at the upper end of the cliff and farther up the run the massive part is thicker.

Another bank showing the disconformity occurs still farther up the run very near the last outcrops of the Bedford shale, where the Berea runs down into the stream. At this locality there is some 2 feet of blue shale at the top of the Bedford. Apparently blue shale occurs at the top of this formation all along this stream, only it does not appear to be at the same stratigraphic horizon in the various outcrops.

The section of Skinner's Run was continued by a study of the outcrops on the higher ground to the southwest of the last bank examined on the stream. On a north and south lane about five-eighths of a mile southwest of the locality just mentioned and 150 feet higher than the top of the Berea sandstone, layers of thin, fine-grained, blue sandstone occur. In the gutter for 15 feet below the sandstone is soft, argillaceous bluish shale which is like the upper part of the Orangeville formation.

This sandstone probably is at or near the base of the Royalton formation.[1]

On the main north and south road from Brooklyn and to the west of the locality just described, the upper part of the Orangeville shale is finely shown along the banks of the highway which had been recently graded when examined in the summer of 1910. The shale shown in the road banks from the base of the hill well toward the summit is all rather soft, bluish or bluish-black in color and weathers into smooth banks. Apparently in this region there is no sandstone in this shale of the Orangeville formation. The lowest sandstone occurs in a bluish, thin-bedded, 6-inch zone which is 135 feet by barometer higher than the top of the Berea sandstone on Skinner's Run more than a mile to the northeast. Next occurs a zone of bluish shale, which is a little gritty, but weathers into smooth shale banks, with a thickness of 14½ feet. Almost at the brow of the hill is the second sandstone zone, 5½ inches thick, which is also thin-bedded, of bluish to greenish color, but as weathered is greatly iron-stained. The sandstones contain some fucoidal marks and similar markings are characteristic of the sandstones at the base of the Royalton formation farther to the southwest in Royalton and Strongville townships. One of these sandstones ought to be considered the base of the Royalton formation and the upper one appears to agree better with the section on Broadview Road, about 1½ miles to the east, although the writer is not positive concerning this point.

The continuation of Broadview Road from where it crosses Skinner's Run at the John Pritsch house to Walling Corners, 4½ miles to the south, affords a good opportunity to study the formations from the lower Bedford to the Sharon conglomerate. This was especially so in the summer of 1910 when part of the road was being graded and paved so that there were fresh exposures of the upper part of the Orangeville and the lower part of the Royalton formations which rendered it easy to determine the line of separation between them.

Section Along Broadview Road from Skinner's Run to Walling Corners.

No.		Thickness. Feet.	Total thickness. Feet.
12.	*Sharon conglomerate.* An old quarry is located on the road one-eighth+ of a mile to the southwest of Walling Corners. The lowest outcrop of the conglomerate occurs on the road just below the quarry and the barometer gave 15 feet from this horizon to the top of the quarry	15	466
11.	*Royalton formation.* The greater part of the formation is more or less covered; but the lower portion was finely shown along the side of the highway, as it had been freshly graded in August, 1910. The thin sandstones		

[1]The name of this formation is proposed and defined in Chapter V of this bulletin (p. 815).

A.—Disconformity between Bedford and Berea formations on Skinner's Run. Middle bank. See page 393.

B.—Thin-bedded sandstone of upper Berea on Broadview Road south of Skinner's Run. See page 395.

No.		Thickness. Feet.	Total thickness. Feet.
	at the base of the Royalton formation are shown on the rather steep slope of the hill between the second and third roads turning east as Broadview Road is followed south from Skinner's Run. The sandstones are thin-bedded, alternating with shale and the thickness is barometric	165	451
10.	*Orangeville formation.* The upper shales of this formation were finely shown along this highway up the lower part of the hill when the section was studied. The lower part of the formation is covered, but its base was assumed to be at the top of the highest outcrops of the thin-bedded Berea sandstone in front of the Hennenger house. This interval, according to the barometer, is 155 feet. It is not improbable that this outcrop does not extend fully to the top of the Berea, and perhaps a few feet of this interval really belongs in that formation	155	286
9.	*Berea sandstone.* Thin, even-bedded sandstone, the layers varying from $\frac{1}{2}$ to 2 inches in thickness and composed of rather fine grains of quartz sand. Some of the layers are ripple-marked. Ten feet in highway cutting in front of the stone house of Mr. H. Hennenger, which is located near the top of the first hill south of Skinner's Run. The general appearance of the upper part of the Berea sandstone at this locality is shown in Plate XLV, B	10	131
8.	Covered interval	20±	121
7.	The old quarry below the Hennenger house and in which the stone used in its constuction was quarried. The upper 2 to 3 feet is thin-bedded, but the remainder is a coarse-grained, thick-bedded sandstone. In the lower part is some cross-bedding	18	101
6.	Covered interval, and not clear to which formation it ought to be referred	3±	83
5.	*Bedford formation.* On road turning to the east below the Hennenger house and not far from the quarry, 4± feet of chocolate shale is shown. The lower portion of this interval along Broadview Road is covered. Thickness barometric	20	80
4.	Chocolate colored shale shown in gutters and banks along Broadview Road. Thickness leveled	30±	60
3.	Olive colored, soft, argillaceous shale with thin layers of similarly colored sandstone in field and along Broadview Road south of Skinner's Run	$13\frac{1}{6}$	30
2.	Covered interval which is all above the top of the black shale on the opposite side of the run	$7\frac{5}{6}$	$16\frac{5}{6}$
1.	Top of black shale at end of bridge on the northern bank of run and just below the John Pritsch house. In this black shale bank are two concretionary layers of sandstone, the upper one thinning out before reaching the bridge and the lower one running obliquely down to the water. As estimated, the base of this section is only $10\frac{2}{3}$ feet higher than the base of the Bedford formation	$9\frac{1}{3}$	9+

It will be seen from the total thickness of the above section, 466 feet, that it is one of considerable thickness and importance in northern Ohio. In this section from the top of the highest outcrop of black shale to the base of the Berea sandstone in the quarry is 74 feet, all of which is clearly in the Bedford formation, unless a part or all of the covered interval of 3 feet at the top belongs in the Berea. To this is to be added the 20 feet from the top of the black shale at the bridge down to the base of the lower sandstone on the cliff below the railroad fill which gives 94 feet for the thickness of the Bedford formation. The thickness of this interval is in close agreement with that of the corresponding one in the section following Skinner's Run which gave 95½ feet. The Berea grit is clearly 48 feet thick, to which perhaps a few feet ought to be added, and on Skinner's Run 55 feet. To the Orangeville is referred 155 feet, of which a few feet at the base ought perhaps to be referred to the Berea, and the lowest sandstone outcrops in the shales on the highway 1½ miles to the west occur 135 and 150 feet higher than the top of the Berea. Finally there is an interval of 165 feet from the base of the lowest thin-bedded sandstone to the lowest outcrop of the Sharon conglomerate at Walling Corners, which is referred to the Royalton formation.

The following diagrammatic section gives the thickness of the exposed formations as shown along Skinner's Run to the top of the Berea and the succeeding ones from the section along the continuation of Broadview Road.

General Section Giving Thickness of Formations on Skinner's Run and Broadview Road.

649′		Walling Corners
	15′	Sharon conglomerate
634′		
	165′	Royalton formation
469′		
	155′	Orangeville shale
314′		
	55′	Berea sandstone
259′		
	95½′	Bedford formation
163½′		
	60½′	Cleveland shale
103′		
	103′	Chagrin formation
0′		Lowest outcrops on Skinner's Run

Sections Near South Park. — As a general rule the immediate banks of the Cuyahoga River are not steep, until the gorge below Cuyahoga Falls is reached, and the tributaries of the river, some from the

western and others from the eastern side, afford better opportunities for studying the various formations. Those which are especially favorable for study are Tinkers and Brandywine creeks on the eastern side and Chippewa and Yellow creeks on the western side. There are smaller streams and other outcrops, either natural or artificial, however, which afford good opportunities for studying one or more of the formations at several localities. One of these is South Park where, on Hemlock Brook and in the quarries in its vicinity, in the southeastern part of Independence Township about 7½ miles south of Newburg Falls, are excellent exposures of the rocks from the upper part of the Chargin formation into the red shales of the Bedford.

At South Park is the extensive plant of the Cleveland Hydraulic-Press Brick Company using the red Bedford shale for its raw material while the sandstone in the lower part of the formation has been worked for some twenty years in the Independence quarry and used for flagging. The following section is compiled from the lower exposures on the bank of Hemlock Brook opposite the Independence Company mill, their stone quarry and the shale quarry of the Hydraulic-Press Brick Company. On the bank of Hemlock Brook the Chagrin and Cleveland shales are shown, at the Independence quarry the upper part of the Cleveland shale and the Euclid lentil of the Bedford formation and in the brick quarry is the red Bedford shale.

Section Near South Park.

No.		Thickness.		Total thickness.	
		Ft.	In.	Ft.	In.
18.	*Bedford shale.* Mainly dark red, almost chocolate in color, argillaceous, fissile shale in Cleveland Hydraulic-Press Brick Company quarry. In the lower part of the quarry there are some streaks of bluish and olive shale and the latter colored shale is shown in the quarry drain. In the upper part of the quarry, when studied in 1901, were large glacial boulders which had evidently settled into the shale from the surface. The shale was quarried with a steam shovel and in 1901 was used alone in the manufacture of brick, although formerly it had been mixed with other shale	25	--	125	7
17.	From the floor of the brick quarry down to the top of the shale in the Independence quarry the barometer gave an interval of 20 feet	20	--	100	7
16.	Olive, argillaceous shale in the upper part of the Independence quarry, which in 1901 was overlain by a stratum 6¼ feet in thickness, composed mainly of till, but there was also some shale	3	9	80	7

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
15.	Apparently the top of the *Euclid lentil.* Zone composed of light-gray, fine-grained sandstone, alternating with bluish, argillaceous shale. There are about 7 layers of sandstone, varying in thickness from $2\frac{1}{2}$ to 10 inches	5	2	76	10
14.	Light-gray, fine-grained sandstone, with thin shale parting at base	--	9	71	8
13.	Light-gray, rather fine-grained sandstone, which is said by the quarrymen to be the best course in the quarry	1	4	70	11
12.	Blue shale to thin sandstones	--	6	69	7
11.	Massive, fine-grained, bluish-gray sandstone which generally separates into two courses	5	9	69	1
10.	Course of thin sandstone	--	3	63	4
9.	Bluish-gray, fine-grained sandstone	1	4	63	1
8.	Course of thin sandstone	--	5	61	9
7.	Light-gray sandstone	1	--	61	4
6.	Blue shale parting	--	3	60	4
5.	Massive layer of bluish-gray sandstone, with parting of blue shale at base	3	1	60	1
4.	Thin sandstone layer and base of *Euclid lentil*	--	6	57	--
3.	Bluish-gray to olive, argillaceous shale. Just below the above shale, which underlies the quarry, was shown 7 feet 1 inch of the massive, black Cleveland shale. This quarry with the overlying till is shown in Plate XLVI, A, while the contact of the Bedford shale (No. 3 of the section) and Cleveland shale, just below the quarry, is indicated by the hammer in Plate XLVI, B	7	--	56	6
2.	*Cleveland shale.* This part of the section was measured on the bank of Hemlock Brook, opposite the Independence Company mill, and the writer is not now certain that the top of the bank reaches to the top of the Cleveland shale. Upper part of bank composed of black, bituminous shale, which splits into thin, even pieces that on the weathered surfaces are frequently brown. Seventeen and one-half feet is shown on the upper part of this bank, so that the formation has at least that thickness and perhaps it is greater, though probably not very much, for on Tinkers Creek, below Bedford, about $4\frac{1}{2}$ miles northeast of this locality, where it was accurately measured, it is only 21 feet 5 inches thick	17	6+	49	6+

A.—Euclid lentil of Bedford formation with overlying till in Independence quarry near South Park.

B.—Contact of Bedford and Cleveland shales just below Independence quarry, shown in Fig. A.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
1.	*Chagrin shale.* The contact between the two shales is very sharp. There is a sudden change from the bluish, argillaceous shales of the Chagrin to the even, black, somewhat gritty ones of the Cleveland. The Chagrin is composed of soft, bluish to olive, argillaceous shales which weather into small pieces, with thin, somewhat calcareous layers, which weather to a rusty color on the surface, and tend to concretionary structure. The upper 32 feet of the Chagrin formation is shown on the bank of the brook opposite the mill from the base of the Cleveland shale to the bed of the stream	32	--	32	--

In the Independence quarry all of the thicker courses of sandstone are worked and all of them according to the quarrymen are used for flagging. The surface of some of the sandstone layers shows ripple-marks and mud-flows. The Euclid lentil of the Bedford formation apparently extends from the top of No. 3 to the base of No. 16, which would give it a thickness of 20⅓ feet. It will be remembered that in the Newburg section the thickness of the Euclid lentil is apparently about 22⅔ feet, which indicates that it has thinned somewhat in passing from the quarries of Euclid Creek to those of the Cuyahoga Valley. In the Newburg sections the bluish-gray shale at the base of the Bedford, below the sandstones, is about 5⅓ feet in thickness and in the Independence quarry 7 feet.

About one mile northwest of South Park and about one-half mile southwest of Independence Station, is Pratt's quarry in the Berea grit. This quarry was formerly worked extensively and the rock used for flagging and grindstones. The highest wall as now exposed afforded the following section:

Section of Pratt's Quarry.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
10.	*Berea grit.* Sandstone at top of the quarry, which is usually even-bedded, but in places cross-bedded	2	10	33 –	--
9.	Thin, even-bedded sandstone	1	9	30	--
8.	Layer which is somewhat cross-bedded, but not so markedly as the subjacent one	3	6	28	3
7.	Strongly cross-bedded zone	6	--	24	9
6.	Zone composed of thin, even-bedded layers of sandstone, varying in thickness from 2 to 6 inches	3	4	18	9

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
5.	Beginning of valuable sandstone at top of massive part of quarry	1	8	15	5
4.	Thickest massive rock in quarry, zone 8 feet thick	8	--	13	9
3.	This zone generally composed of three layers of sandstone	2	2	5	9
2.	Light-gray, in places bluish-gray, coarse-grained sandstone to grit	1	2	3	7
1.	Layer lithologically similar to the one above, and its bottom forms the base of the quarry as shown in 1901	2	5	2	5

All of the nearly 30 feet of rock shown in the above quarry belongs in the Berea grit and as neither the top nor the bottom of the formation was clearly shown, it cannot be said that it is not considerably thicker. The structure of the upper part of the quarry, however, is in close agreement with that of the upper part of the Berea grit in neighboring sections where this limit of the formation is clearly shown and hence it is thought that practically the top of the formation is shown in this quarry. As was seen in Euclid Creek and will be described in Chippewa Creek, four miles south of this quarry, the topmost layers of the Berea grit are even-bedded, beneath which is a very conspicuous, strongly cross-bedded zone of varying thickness. This is essentially the structure of the upper part of Pratt's quarry and consequently indicates the top of the formation.

On Tinkers Creek near Bedford, 5+ miles east of Pratt's quarry, the Berea grit has a thickness of 39$\frac{1}{3}$ feet while on Chippewa Creek, near Brecksville, the barometer gave a thickness of 40 feet. It appears probable that the base of the Berea grit is 6 or 7 feet lower than the bottom of Pratt's quarry and that the thickness of the formation is not far from what it is in the neighboring localities which have been cited above. From the base of the quarry down to the top of the Cleveland shale the barometer gave 106 feet and if we call the thickness of the Berea grit about 39 feet as in the Tinkers Creek section, which was the more accurately measured of the two cited above, then the thickness of the Bedford formation in the vicinity of South Park will be about 100 feet.

The following diagrammatic section shows the thickness of the exposed formations near South Park as shown from the bed of Hemlock Brook to the top of Pratt's quarry.

Section Giving Thickness of Formations Near South Park.

188½′	39′±	Top of Pratt's quarry Berea grit, 33 feet seen; thickness called 39 feet from Tinkers Creek		
149½′	72⅔′±	Bedford shale Only lower part exposed Thickness estimated		Bedford formation Thickness about 100 feet, which was partly estimated
76⅚′	20⅓′	Euclid lentil	Thickness measured	
	7′	Shale zone		
49½′	17½′+	Cleveland shale		
32′	32′	Chagrin shale		
0′		Bed of Hemlock Brook opposite the Independence Co. mill		

Tinkers Creek Sections Near Bedford. — Tinkers Creek enters the Cuyahoga River from the east only about three-fourths of a mile south of South Park,[1] and the various sections on its banks vary in distance from 2½ to 5 miles north of east of South Park. The lower course of the stream for some miles is, in general, southwesterly and below and opposite Bedford it has cut a gorge of considerable depth which for part of the distance is bordered by steep and high banks. It was studied by Dr. Newberry whose writings have made it well known to geologists, especially since he named the Bedford formation from the outcrops on its banks in Bedford Township, opposite Bedford village. The gorge part of Tinkers Creek is now known as "the glen" and nearer the village there is a park and pavilion above it.

The entire length of Tinkers Creek was not examined; but it was followed down stream from the high bank under the A. B. & C. electric bridge near Bedford until the upper 50 feet of the Chagrin formation had been studied. In the description, however, it will be considered in the reverse order and beginning with the lowest outcrops examined. The upper 50 feet of the Chagrin formation is composed mostly of a fine, bluish, argillaceous shale in which occur, at irregular intervals, thin layers of calcareous rock, which weather to a rusty color. Fossils occur in both the shales and the calcareous layers; but they are not

[1]South Park is incorrectly located on the Cleveland sheet where the name is printed on the eastern side of the river opposite the name Tinkers Creek. South Park is located on the western side of the river and the highway three-fourths of a mile farther north.

abundant, in fact scarcely frequent enough so that they might be considered common.

Near the lower end of Tinkers glen the upper part of the Chagrin shale is rather fossiliferous. The fossils occur most abundantly in thin layers of the bluish, arenaceous to argillaceous shale, which alternates with an occasional thin calcareous layer about an inch in thickness. The best locality for collecting is on the southern bank from about 2½ feet to perhaps 4 feet below the base of the Cleveland shale. The most abundant species are *Camarotœchia sp.* and *Dalmanella tioga* (Hall) Wms. while *Spirifer disjunctus* Sowb. is next. The following species were collected from this horizon at this locality in about two hours:

1. Spirifer disjunctus Sowb. (c)
2. Dalmanella tioga (Hall) Wms. var. elmira Wms. (a)
3. Productella hirsuta Hall (r)
   Good specimens; one ventral valve shows long spines from the hinge-line and the bases of others over the surface of the valve.
4. Athyris polita Hall (a)
5. Camarotœchia orbicularis Hall (a)
   There are some small specimens which approach in outline small ones of *C. eximia* Hall; but probably they are young forms of *C. orbicularis* Hall. Most of the larger specimens clearly have the suborbicular outline of this species.
6. Camarotœchia contracta Hall (rr)
7. Liorhynchus mesicostale Hall (?) (r)
   Specimens are more or less flattened in the shale and perhaps they are *L. globuliforme* (Van.) Hall var. *chagrinanum.*
8. Chonetes scitulus Hall (c)
9. Productella lachrymosa (Con.) Hall (r)
10. Lingula sp. (rr)
11. Orthoceras bebryx Hall var. cayuga Hall (?) (r)

The species enumerated in the preceding list were collected by Mr. Morse and the writer at this locality in the summer of 1907. At an earlier date the writer had collected the species recorded in the two following lists, at this locality. A layer of fairly coarse arenaceous, bluish shale contained the following species:

1. Spirifer disjunctus Sowb. (c)
2. Dalmanella tioga (Hall) Wms. (rr)
   This species was described by Hall under the generic name of *Orthis* and referred to the genus *Schizophoria* by Hall and Clarke (Pal. N. Y., Vol. VIII, pt. I, 1892, p. 212), which has been accepted in the majority of recent paleontologic papers, including Schuchert's Synopsis of Am. Fossil Brachiopoda (Bull. U. S. Geol. Survey, No. 87, 1897, p. 375). Professor Williams, however, referred it to the genus *Dalmanella* (ibid., No. 244, p. 36, f.n.a) and stated

that "The Schizophorias are common below the Chemung, but they are rare in the Chemung until the upper part is reached, while the Dalmanellas are among the first forms to appear at the incoming of the Chemung fauna, and they are conspicuous representatives of the Chemung fauna." Dr. Kindle, however, who was associate author of this bulletin with Professor Williams, retains it in the genus *Schizophoria* (Jour. Geology, Vol. XIX, 1911, p. 349).

3. Athyris polita Hall (?) -- (rr)
4. Camarotœchia cf. eximia Hall or C. stevensi Hall -------------- (c)
   The specimens are broken and poorly preserved; but with 20 or more plications. They bear some resemblance to *C. contracta* Hall; but this species has only from 16 to 20 plications. A small specimen with 22 or more plications resembles considerably a flattened one of the original of fig. 1 of *C. eximia* (Pal. N. Y., Vol. IV, pl. 55), in the American Museum, that has about 11 plications on each side of the shell. The Ohio specimen is probably a young form and therefore it is not advisable to insist too strongly upon the similarity, since the larger specimens do not agree so well with this species.
5. Productella cf. striatula Hall -------------------------------- (r)
6. Leptodesma sp. -- (rr)
   Imperfect specimen.
7. Specimen like Orbiculoidea herzeri Hall and Clarke------------- (rr)
8. Lingula sp. --- (rr)

At the top of the Chagrin shale in this glen the following species were obtained:

1. Spirifer disjunctus Sowb. -------------------------------------- (c)
   Ten specimens of this species were obtained in this layer.
2. Camarotœchia orbicularis Hall (?) ----------------------------- (c)
   Professor Whitfield agreed with the writer that a large specimen from this locality probably belongs to this species. He thought that two additional specimens might belong to the same species; while two other small ones he concluded might belong to a different species, although he would not attempt to name it.
3. Athyris cf. polita Hall -- (rr)
   Crushed specimens.
4. Actinopteria sp. or Liopteria sp. ------------------------------ (rr)
   Specimens too badly broken to decide to which genus they belong.

It is to be remembered that Dr. Newberry in No. 9 of his section of strata at Bedford gave *Leiorhynchus mesacostalis* = *Liorhynchus mesicostale* Hall and *Spirifer disjunctus* as occurring in the Erie shale (= Chagrin).[1] Perhaps some of the specimens of *Camarotœchia* might be compared with *Liorhynchus laura* Bill. (= *L. multicosta* Hall), which

[1]Geol. Surv. Ohio, Vol. I, p. 197.

some of the individuals flattened in the shale considerably resemble. They have about twenty plications which are too conspicuous on the sides for *L. mesicostale* Hall.

This fauna is considered by the writer to be a Chemung one as is fully stated in other parts of this bulletin. This opinion is apparently in agreement with that of Dr. Kindle who has stated concerning this particular locality that he "found immediately below the Cleveland shale a Chemung fauna without any trace of Waverly species."[1]

The fossils of the above lists came from the horizon of the 4 feet called an "hydraulic limestone" by Dr. Newberry in his "Section of Strata at Bedford," which is No. 8 of that section and directly subjacent to the Cleveland shale. Dr. Newberry described it as an "hydraulic limestone with *Macrodon* and *Syringothyris*;"[2] but at the locality examined by the writer it is mainly a bluish, argillaceous shale, although a foot and seven inches below the base of the Cleveland shale is a calcareo-arenaceous layer a foot in thickness.

This is probably the supposed horizon concerning which at a later date Dr. Newberry wrote as follows: "Mr. Andrew Sherwood, one of my assistants, * * * brought to me fragments of an earthy limestone which he claimed to have found in the valley of Tinkers Creek near Bedford, Ohio, '*beneath the Cleveland shale.*' These specimens contained numerous Waverly fossils, among which *Syringothyris typus* was conspicuous. Subsequently, when a question was raised in regard to the accuracy of these observations, efforts made to rediscover the stratum of limestone reported by Mr. Sherwood were without success."[3]

The specimens collected by Mr. Sherwood probably came from a somewhat massive and calcareous layer in the Bedford formation or from the calcareous zone at the base of it. Blocks of the massive impure magnesian limestone were noticed by the writer loose in the creek and some washed down it may have been supposed by Sherwood to occur *below* the Cleveland shale or perhaps he may have made a mistake in his notes and written *below* when *above* the Cleveland shale was intended. Loose blocks of the impure limestone found at this locality were sampled and analyzed by Assistant Professor D. J. Demorest of Ohio State University, with the following result:

Silicious residue	Clay	17.5
	Quartz	5.8
	Feldspar	10.8
Al_2O_3		2.03
Fe_2O_3		9.30
$CaCO_3$		34.60
$MgCO_3$		17.05
		97.08

[1]Am. Jour. Sci., 4th ser., Vol. XXXIII, 1912, p. 132.
[2]Geol. Surv. Ohio, Vol. I, p. 197.
[3]Mon. U. S. Geol. Survey, Vol. XVI, 1889, p. 127.

A copy of the above analysis together with a sample of the rock was sent Prof. Albert Johannsen, who wrote as follows: "The rock you sent is one of those interesting rocks to which one cannot give a very satisfactory name. From the analysis I should say it is a siliceous magnesian limestone."[1] Another copy of the analysis together with a similar sample of the rock was sent Prof. James F. Kemp, who wrote as follows: "I have had a good look at the specimen from the Bedford formation. It obviously presents the same difficulties which the old geologists of New York State met when they worked upon the Beekmantown limestone and called it calciferous sand rock. My disposition would be to describe this as a siliceous magnesian limestone. It would probably be described by many also, and quite correctly, as an earthy magnesian limestone. I think I should prefer to do this to considering it a calcareous sandstone or shale."[2]

Similar information, together with a sample of the rock, was sent Prof. A. C. Gill who wrote that he found the iron oxide chiefly present "as FeO and hence I should think it probable that it occurred in the condition of $FeCO_3$ making the rock an impure ankeritic dolomite."[3]

In reference to its horizon Prof. H. P. Cushing wrote as follows:

"Your small chunk of rock came this morning, and matches exactly with my material. * * * [It] seems to me unquestionably identical with my stuff from 40 feet above the base of the Bedford in the Tinkers Creek gorge. It is * * * often crammed with Macrodon shells, with occasional Rhynchonella in addition. It is also the only horizon and locality in which I have found Bedford fossils in northern Ohio, except in the basal few feet. Loose pieces of the stuff would naturally be expected in the gorge."[4]

From the calcareous layer at the base of the Bedford formation in Tinkers Creek and from loose blocks of the impure magnesian limestone found in the creek, the writer has collected *Syringothyris carteri* Hall(?) (=*S. typus* Winch.) and *Parallelodon* (*Macrodon*) *hamiltoniæ* Hall. Other species also occur, but these are the two mentioned by Dr. Newberry in the "hydraulic limestone" and it appears probable that the specimens which he saw came from the same layer. The writer has not seen an hydraulic limestone at the top of the Chagrin formation although he has studied a considerable number of sections where the contact of the Chagrin and Cleveland shales is shown.

Dr. Kindle recently studied this locality and also reached the conclusion that the *Syringothyris* fauna did not come from *below* the Cleveland shale. His statement is as follows: "It was in this volume [1874

[1]Letter of Oct. 27, 1911.
[2]Letter of Nov. 14, 1911.
[3]Letter of Feb. 6, 1912.
[4]Letter of Oct. 14, 1911.

Report] that Newberry published the list of Waverly fossils, including *Syringothyris typa*, which he reported to have been found below the Cleveland shale. It appears that the authenticity of this find was called in question during Professor Newberry's lifetime, and in a later discussion of the matter he states that these fossils were collected by an assistant who was not able to relocate the horizon when requested to do so. The writer and Mr. P. V. Roundy searched very carefully the section from which this fauna was reported to have been obtained, but found immediately below the Cleveland shale a Chemung fauna without any trace of Waverly species. Many other geologists have studied the northern Ohio sections since Waverly fossils were reported by Newberry from below the Cleveland shale, but not one, so far as the writer is aware, claims to have found Waverly fossils at this horizon. In view of these facts I think we may safely conclude that the collector of this fauna incorrectly identified the formation from which his Waverly fossils came."[1]

Dr. Ulrich has recently stated that "it is to be understood that these Jefferson specimens [of *Syringothyris*] have nothing to do with those mentioned many years ago by Newberry as having been found in a similar position at Bedford. All agree now that the latter came out of some Bedford float which had gone down stream."[2]

Below the above described zone Dr. Newberry gave 60 feet of the Chagrin formation (Erie shale) as exposed which was No. 9 of his section and described as a "green shale (Erie shale) with *Leiorhynchus mesacostalis*, *Spirifer disjunctus*, etc." There are several excellent exposures of the upper part of the Chagrin formation and the Cleveland shale capped by the lower part of the Bedford formation on the banks of this creek below the old woolen mill.

Near the lower end of the glen the following section is well shown on the northern bank:

Section on Tinkers Creek Below Bedford Glen.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
10.	Mainly fine-grained, bluish sandstone with some layers of shale, which forms the upper part of the bank and was measured farther up the stream. Base of *Sagamore lentil of the Bedford formation*, which will be described later	23	--	93	7
9.	Bluish, argillaceous shale, with some that is arenaceous	4	6	70	7
8.	Blue, fine-grained sandstone	--	3	66	1
7.	Bluish, argillaceous and arenaceous shale. Base of *Bedford formation*	36	--	65	10

[1]Am. Jour. Sci., 4th ser., Vol. XXXIII, p. 132.
[2]Ibid., Vol. XXXIV, p. 179, f. n.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
6.	*Cleveland shale.* Black, bituminous, compact shale, thick blocks of which occur farther up the stream in its bed, and when freshly broken, have a strong petroleum odor. Farther down the stream where the top and bottom limits are sharply defined, a vertical measurement on the face of a cliff gave a thickness of 21 feet 5 inches. This is in close agreement with Newberry's measurement of 21 feet for No. 7 of his Bedford section, which was described as a "Black bituminous shale, (Cleveland shale) with fish teeth and scales."[1] The contact of the Cleveland shale and the Chagrin formation on the steep cliff somewhat farther down the glen, is shown in Plate XLI, A. The upper portion, with the coarser layers, is the Cleveland shale, its base formed by the lowest conspicuous and somewhat projecting layer	21	2	29	10
5.	*Chagrin formation.* Top layer bluish, argillaceous shale	1	7	8	8
4.	Calcareo-arenaceous layer	1	--	7	1
3.	Bluish, argillaceous, fossiliferous shale	5	--	6	1
2.	Calcareous layer	--	2	1	1
1.	Blue, argillaceous shale, containing fossils, to creek level	--	11	--	11

A gully on the northeastern bank farther up the stream than the point at which the above section was measured, and below the gully leading up to the spring, gave the following section:

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Sagamore lentil of the Bedford formation,* consisting of sandstones with shale partings. The sandstones are bluish, fine-grained, and more or less irregularly bedded, with an occasional layer showing ripple-marks. Some of it weathers to a rusty color	23	$64\frac{1}{3}$
2.	Blue, argillaceous and arenaceous shales, with thin sandstones, varying in thickness from 1 to 4 inches and occurring at irregular intervals	$41\frac{1}{3}$	$41\frac{1}{3}$
1.	Top of *Cleveland shale* is shown at the top of the covered interval.		

At one point in the glen there is a dip of 4° up stream and in measuring the Cleveland shale when following the stream only $16\frac{1}{3}$ feet was obtained, which probably did not extend quite to its top.

[1]Geol. Surv. Ohio, Vol. I, p. 197.

On the southwestern side of the creek the contact of the Cleveland shale and Bedford formation is well shown near the water's edge when the stream is not high. The basal 2 inches and perhaps more of the Bedford is a gray arenaceous and somewhat blocky shale which contains numerous fossils, although the number of species does not appear to be so great as in the Euclid localities. *Syringothyris* is common in this zone. At one point rather poorly preserved specimens of a (?) *Camarotœchia* sp. and a gastropod were found in the extreme upper part of the black shale just below the base of the Bedford. Fossils are not uncommon in the lower 2 feet of the Bedford which is composed of blue shales and thin lenticular layers of somewhat impure limestone. An occasional specimen of *Camarotœchia* was found in the blue shales for 10 feet or more above the base of the formation. Near its base are also sandstones, varying in thickness from 2 to 3 inches, which contain a considerable amount of iron pyrites or marcasite.

On the southwestern side of the creek and a few rods farther up stream than the contact described above, is a high and steep cliff in which the greater part of the Bedford formation is shown capped by the Berea grit. This cliff is shown in Plate XLVII, where the following section was obtained:

Section of Vertical Cliff in Bedford Glen.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Berea grit.* It forms the upper part of cliff, perhaps 30 feet, but not measured	30±	77±
3.	*Bedford formation.* Upper portion consisting of bluish-gray to bluish shales, alternating with thin layers of sandstone	25	47
2.	*Sagamore lentil.* Bluish, fine-grained sandstones	22	22
1.	Blue, argillaceous and arenaceous shales, with thin sandstones to bed of creek, but not measured.		

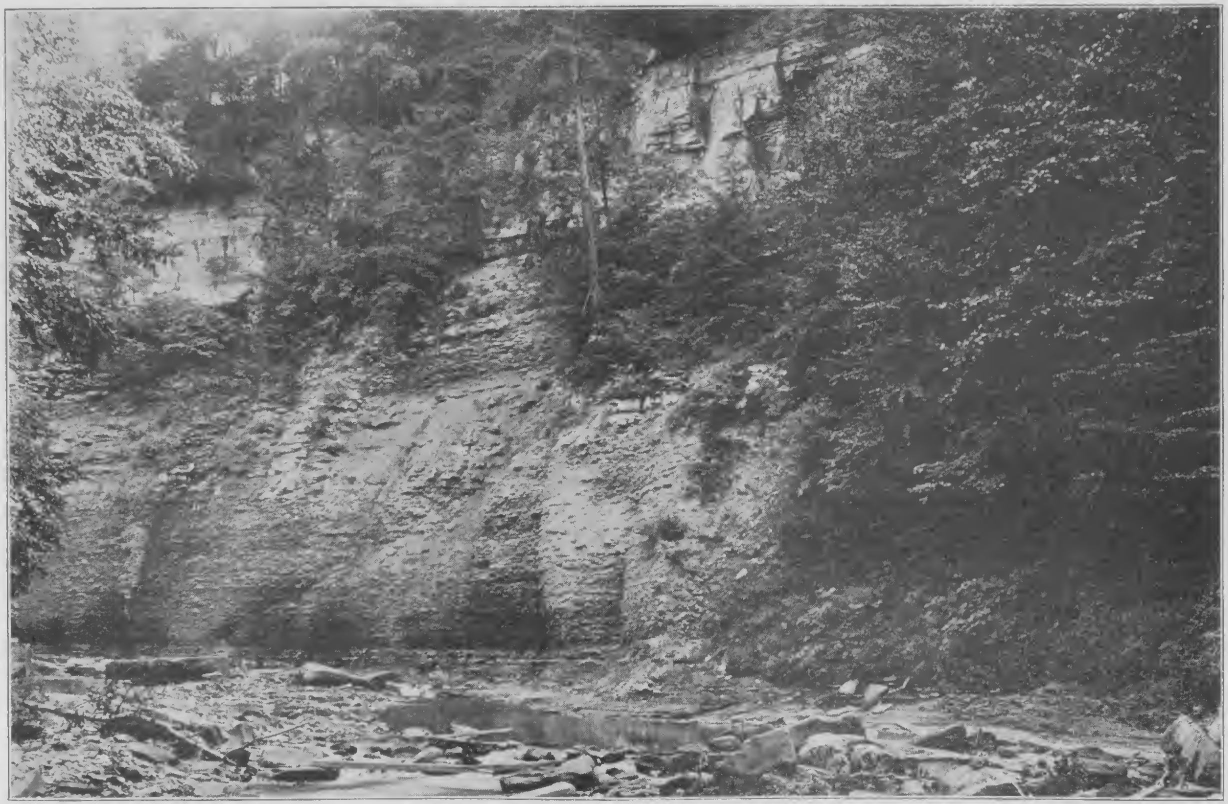
This steep bank was measured by Mr. Morse who obtained by hand level a thickness of 45 feet from the base of the Sagamore lentil to the base of the Berea grit, or 47 feet by tape for the same interval. By tape the Sagamore sandstone was 22 feet in thickness and the superjacent zone of shale 25 feet.

This high cliff together with the banks farther down the stream has furnished the following general section of the rocks in Tinkers Creek at Bedford Glen:

Section of Tinkers Creek at Bedford Glen and Below.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Berea grit.* Perhaps 30 feet, but not measured	30±	189±
3.	*Bedford formation.* Upper portion consisting of bluish-gray to bluish shales, alternating with thin layers of sand-		

PLATE XLVII.



Cliff in Bedford Glen on Tinkers Creek showing Bedford formation capped by Berea grit. Typical locality of Bedford.

No.		Thickness. Feet.	Total thickness. Feet.
	stone, 25 feet on high cliff. *Sagamore lentil,* 22 feet on high cliff and 23 feet on opposite side farther down the stream. Lower portion consisting of blue, argillaceous and arenaceous shales, with thin layers of sandstones, varying in thickness from $40\frac{1}{4}$ to $41\frac{1}{3}$ feet. If 22 feet be accepted for the thickness of the Sagamore lentil, and 41 feet for that of the lower shale, then the thickness of the Bedford formation will be 88 feet	88	159
2.	*Cleveland shale*	21	71
1.	*Chagrin formation.* The upper 9 feet of this formation, as it occurs near the lower end of the gorge, has already been described. Lower, the shale is mainly fine, bluish and argillaceous, with an occasional harder layer of calcareous rock, which weathers to a rusty color. The upper 50 feet of the formation as shown on this creek was seen, but probably not the outcrops along the lower 2 miles of it	50	50

The writer was informed that the Cleveland shale at this locality is so compact that it has been used as an abrasive. It was stated that from the bank near the dam and old woolen mill, a carload of it had been shipped. The shale as shown in the bed of the creek and on its banks in the glen when not weathered is certainly very compact and massive.

On the southern bank of the stream in the glen nearly the entire thickness of the Bedford formation is shown in the vertical cliff described above, capped by the Berea grit. The lower and upper portions of the Bedford formation at this locality, which is the typical one, are composed largely of fairly thin, bluish or bluish-gray, argillaceous to arenaceous shales alternating with layers of thin sandstone. Near the middle of the formation is the Sagamore sandstone lentil, the sandstones of which appear to be rather prominent on the cliff as seen from the creek.

On the northeastern bank, a few rods farther down the stream than the vertical cliff on the opposite side, is a steep bank in which the middle portion of the formation is well shown. The following section at this locality was leveled by Mr. Miller:

Section on Northeastern Bank in Bedford Glen.

No.		Thickness. Ft.	In.	Total thickness. Feet
6.	*Berea grit.* Not measured.			
5.	*Bedford formation.* A considerable portion of the upper part of the formation covered. Shales and thin sandstones shown toward the top. The sandstones are ripple-marked and these marks run			

No.		Thickness. Ft.	In.	Total thickness. Feet.
	N. 22° W. Lower part composed of gray, as weathered, fine-grained sandstones, some layers 2± feet in thickness, the layers separated by shales	39	9	$85\frac{3}{4}$
4.	Gray shale	2	4	46
3.	Blue, somewhat calcareous layer, which changes to more of a sandstone as exposed on the path from the creek up to the dancing hall. On the path it is 9 inches thick. Base of the Sagamore sandstone lentil	--	$6\frac{3}{4}$	$43\frac{2}{3}$
2.	Gray to blue shales, both arenaceous and argillaceous, with layers of thin, platy, gray sandstone, 1 to 3 inches thick; but the shales predominate and the sandstones are not close together. The Bedford is exposed nearly down to the Cleveland, the top of which is shown on the bank a little farther down stream	43	2	$43\frac{1}{6}$
1.	*Cleveland shale.*			

That portion of the Sagamore lentil shown in the above section appears to be composed of generally thicker layers of sandstone with less shale than in the vertical cliff on the opposite side of the creek. In the cliff on the southwestern side a considerable proportion of the Sagamore lentil is composed of thin-bedded sandstones to coarse shales.

The section of the Bedford formation on Tinkers Creek in the Bedford Glen differs strikingly from the section of the same formation at South Park, only $4\frac{1}{2}$ miles to the southwest. At South Park there is 7 feet of bluish-gray shale capped by the Euclid sandstone lentil with a thickness of $20\frac{1}{3}$ feet, making its top $27\frac{1}{3}$ feet above the base of the formation; while in the Bedford Glen there is about 41 feet of blue shales and thin sandstones before reaching the base of the sandstone zone which varies in thickness from 22 to 23 feet. It therefore follows that the *base* of the sandstone lentil in the Bedford formation at Bedford is nearly 14 feet higher stratigraphically than the *top* of the Euclid sandstone lentil at South Park. Consequently the sandstone zone at Bedford appears to occupy a higher stratigraphic position in the Bedford formation than that of the Euclid lentil and for this reason it has been given a distinct name, viz., the *Sagamore lentil.* The zone of "blue flagstone" constituting the Euclid lentil as described at South Park, Newburg and Euclid Creek is scarcely represented at Bedford. There are some bluish-gray sandstones near the base from 2 to 3 inches thick, or perhaps even thicker; but the rocks are principally bluish to bluish-gray shales, some of which are rather gritty. On account of the absence of conspicuous sandstone layers in the lower part of the formation no attempt is made to

indicate the position of the Euclid lentil which has practically changed to shale. Again the reddish or chocolate shale which so generally occurs in the upper part of the Bedford formation from the Cuyahoga River westward, as at South Park, is absent.

This locality is the typical one for the Bedford formation where Dr. Newberry stated that "the best exposure of the Bedford shale" is to be found and hence "it has received its name from this fact."[1] He also stated that beneath the Berea sandstone in the gorge of Tinkers Creek at Bedford "we find 70 feet of *blue* shale" and "no red shale is visible."[2] This is No. 6 of his section at Bedford which is there given as 71 feet in thickness and described as "blue shale (Bedford shale) with many fossils—*Syringothyris*, etc.—at base."[3] The thickness of the Bedford formation at this locality as measured by Mr. Morse and the writer is 88 feet or 17 feet greater than that given by Dr. Newberry.

Prof. C. L. Herrick published a section of the "Cuyahoga Valley and Bedford" concerning which he stated that "The figures are all actual measurements, there being no composition of different partial sections, and are as nearly accurate as need be."[4] The exact localities at which the measurements for the different parts of the section were made are not given; but since Bedford occurs in its title it appears reasonable to suppose that the measurements for the Bedford formation were made near that village. Professor Herrick's section of the Bedford is as follows:

"Blue to green Bedford shale	45 ft.
Flags	10 ft.
Soft fossiliferous shale	25 ft.
Flags	10 ft."[5]

The total thickness of Herrick's section is 90 feet, or 2 feet greater than the one reported by the writer; but the two zones of flags do not agree with his observations. As already described, a 22-foot sandstone zone was found near the middle, but no 10 feet of flags at either the top or bottom of the formation.

The following fossils were obtained from the Bedford formation in the glen. Loose blocks of a somewhat massive and calcareous layer furnished part of the fauna. The following is a partial list of the species collected at this locality:

1. Syringothyris carteri Hall (?)
   Imperfectly preserved specimens, which it is not improbable came from the same layer of argillaceous limestone as the

[1]Geol. Surv., Ohio, Vol. I, p. 189.
[2]Ibid., p. 188.
[3]Ibid., p. 197.
[4]Bull. Geol. Soc. America, Vol. II, 1891, p. 39.
[5]Ibid., p. 40.

as one in which the specimens identified by Dr. Newberry *S. typa* Winch = *S. carteri* Hall (Mon. U.S. Geol. Survey, Vol. XVI, p. 127) were obtained. Herrick at one time apparently questioned the occurrence of *Syringothyris typa* in the Bedford, since he wrote that "In the characteristic chocolate beds of the Bedford in the Cuyahoga valley and near Columbus the same association of forms has been found, with *no admixture* of *Waverly species.* This we desire to make prominent in view of the published statement of Dr. Newberry, that *Syringothyris,* etc., occur in the Bedford" (Am. Geologist, Vol. III, Feb. 1889, p. 97). Concerning the identification and occurrence of this species in the Bedford formation, it may be stated, that in the Geological Museum of Ohio State University are specimens labeled *Syringothyris typa* Winch., imbedded in shale, which the catalogue states are from the Bedford shale at Bedford, Ohio, and others from the same formation at Northfield, Ohio. This material probably came to the University as part of the collection from the State Geological Survey, and had been identified and labeled either by or under the direction of Dr. Newberry. The Geological Museum of Columbia University also contains specimens labeled "*Syringothyris typa,* Bedford shale, Bedford, Ohio." These specimens, it is also understood, came to the Museum through Dr. Newberry. The shale containing the specimens of this species, in both the Ohio State and Columbia museums, certainly has the lithologic appearance of dark gray shale from the Bedford formation of northern Ohio. Professor Schuchert also reported this species from the Bedford shale at Bedford (Ninth Ann. Rept. State Geologist [N. Y.], 1890, p. 32, and in his Synopsis of Am. Fossil Brachiopoda, Bull. 87, U. S. Geol. Survey, 1897, p. 441). Later, Professor Herrick admitted the occurrence of the genus *Syringothyris* in the Bedford; but apparently considered the species distinct from *S. typa* (Bull. Geol. Soc. America, Vol. II, 1891, p. 34).

2. Camarotœchia cf. sageriana Winch.

These specimens are not well preserved, and have not been compared with type specimens of this species. This species, however, was reported by Dr. Newberry from the Bedford (Geol. Survey Ohio, Vol. III, p. 23). A specimen from Medina, Ohio, in the Columbia University Museum, labeled *Rhynchonella sageriana,* has 4 plications on the fold and 6 or 7 on each side of it. The number of plications agrees fairly well with that of the Bedford specimens; but those of the Medina specimen are a little more angular than those of the Bedford.

In the American Museum, the originals of figs. 48–52, pl. 55, Vol. IV, Pal. N. Y. of *C. sappho* Hall var. from the Waverly of Licking County, Ohio, were studied. These are rather large specimens, which have coarse plications, with 6 on the fold, 5 in the sinus and 5–7 on each side. These specimens have rather more and coarser plications

than those from the Bedford shale. The Bedford specimens have 3 or 4 plications in the sinus, with 5 on the fold, and about 4 on each side. It does not appear that the Bedford specimens agree very closely with this species or its variety. Professor Whitfield referred them to *C. contracta* Hall; but the plications are not so sharp as those of that species, and the form is more angular. This statement is true of the original of fig. 39, pl. 55, Vol. IV, Pal. N. Y., from Licking County, Ohio, which was referred to this species by Professor Hall. Dr. Girty in his paper on "The Geologic Age of the Bedford Shale of Ohio" lists *Camarotœchia sappho* as in the Bedford.

3. Ambocœlia umbonata (Con.) Hall (?)
4. Palæoneilo bedfordensis Meek

   Good specimens of this species
5. Parallelodon hamiltoniæ Hall

   One specimen shows clearly the interrupted radiating striæ. Professor Hall reported that "a form undistinguishable from this species [*P. hamiltoniæ*] occurs in the soft shales at Bedford, Cuyahoga County, Ohio" (Pal. N. Y., Vol. V, pt. I, Lamellibranchiata II, p. 350). The original of fig. 7, pl. 51, from Bedford, Ohio, was studied in the American Museum of Natural History in New York, where is also the original of fig. 1 of the same plate from New York. The Bedford specimen apparently has all the characteristic markings of it as shown by type and authentic specimens of the species from the New York Hamilton. Ohio specimens were shown Professsor Whitfield, and the only difference he noted is in the hinge line, which he thought is not so straight in the Bedford specimens as in the Hamilton ones. The difference, however, between these two type specimens is to the writer not marked, and it would appear like a very slight difference upon which to base the description of a new species. In the State Museum at Albany, New York, the originals of figs. 2–6 and 9 of pl. 51 were studied, and Ohio specimens compared with them. Certainly the Ohio Bedford specimens are very similar to those from the Hamilton of New York, since the markings and proportions are almost identical. The close similarity of the proportions is shown by the following comparison between the original of fig. 3, pl. 51, from the Hamilton, south of Cardiff, New York, and one from the Bedford shale on the bank of Black River, two miles north of Elyria, Ohio. The New York specimen has a length of 21.7 mm. and a height of 12 mm.; while the Ohio specimen has a length of 22.4 mm. and a height of 12.5 mm. The height in each instance was measured a little posterior to the umbone. The New York specimen is a little thicker than the Ohio one; but perhaps this is due to the slight crushing of the latter in the softer shale. Since these specimens are so very similar, it appears almost useless to attempt to separate specifically the Bedford ones from the Hamilton.
6. Leda diversa Hall var. bedfordensis Herrick

A specimen from the limestone in the Bedford of Tinkers Creek was compared with the original of fig. 34, pl. 47, Lamellibranchiata II, pt. 1, Vol. V, Pal. N. Y., which is from the Hamilton beds at Summit, N. Y., and the specimens are certainly very similar. It appears that the varietal name is sufficient recognition of such difference as exists between them.

7. Conularia newberryi Winch. (?)

The specimen has 12 to 15 crenulations on transverse striæ in $\frac{1}{10}$ of an inch, which are apparently more than the description calls for. Also on part of the specimens there are apparently transverse striæ on the furrows.

8 Bellerophon sp.

9. (?) Goniatites sp.

Prof. C. L. Herrick reported that in the Bedford at "the typical locality at Bedford *Macrodon hamiltonæ, Microdon bellistriatus, Leda diversa, Palæaneilo* [*Palæoneilo*] *constricta* and *Chonetes scitula* are found 40 feet below the Berea grit. It is true that the forms identified by Newberry, and upon which the Carboniferous age of the Bedford has been maintained, do occur associated with *Macrodon hamiltonæ*; but, so far as observed (and I think I have seen most of the specimens), they are thus associated in the bands of flags intercolated with the shale and not in the shale itself. However that may be, out of the list quoted, *Syringothyris typa* and *Spiriferina solidirostris* are the only species which could carry conviction; the others are either too widely distributed or too closely allied with Devonian types to be positively identified from crushed and imperfect specimens. As to the Syringothyris, after careful examination I incline to think it distinct from the species characteristic of the middle Waverly, while it is very rarely found in the shales 100 feet above the Berea."[1]

Above the glen is the Pennsylvania Railroad viaduct and on the northeastern bank of the creek was formerly an excellent section.

Section Above the Pennsylvania Railroad Viaduct.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
7.	*Aurora sandstone.*[2] Mainly thin-bedded, light-gray sandstone, with shale partings to top of bank. At base, thin-bedded, light-gray, fine-grained sandstone. Sandstone zone which is generally found between the Brecksville shale and the Sunbury shale	7	6	71—	--
6.	*Sunbury shale.* Blackish shale near top of member. Very fine, argillaceous shale				

[1]Bull. Geol. Soc. America, Vol. II, 1891, p. 34.

[2]This sandstone member of the Orangeville formation is named and described in Chapter II of this bulletin (p. 532).

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
	which is mainly bluish-gray to gray in color, but with some blackish layers. This shale is finely shown on the bank above the quarry, as may be seen in Plate XLVIII, where it is opposite the man, and its top indicated by his hand	6	--	63	4
5.	*Berea grit.* Light-gray or rusty-brown in color and rather harder and finer grained sandstone than the lower layers	3	2	57	4
4.	Massive, light-gray grit, which often weathers yellowish	3	8	54	2
3.	Light-gray or often weathered to a rusty-yellow, thin-bedded to shaly sandstone	3	2	50	6
2.	Massive, light-gray, coarse-grained sandstone to grit. Ripple-marks occur in lower part. The base of the Berea is a massive sandstone below which is the softer, bluish, Bedford shale, which has been eroded, leaving a projecting ledge of the Berea sandstone. This contact was formerly well shown on the bank of Tinkers Creek, some rods above the Cleveland and Pittsburgh Railroad viaduct	29	4	47	4
1.	*Bedford formation.* Upper part of Bedford composed of bluish-gray, argillaceous shales. Lower part of exposure consists of shales, alternating with thin layers of sandstone, 1 inch or more in thickness, to creek level	18	--	18	--

Since the above section was measured, the Pennsylvania Railroad has made the big fill and viaduct a little below this point. The eastern bank, however, below the Electric Light Plant and opposite one of the Taylor Chair Company buildings, shows the section fairly well. The upper part of the Sagamore lentil makes the cascade in the creek, above which is the upper shale and thin sandstone zone of the Bedford, which is capped by the massive Berea that makes the fall in the creek. On the eastern bank below the Electric Light Plant, the upper part of the Bedford is partly covered; but the contact between it and the Berea is shown. Above may be seen the Berea grit, the Sunbury shale and the Aurora sandstone.

In the above section the entire thickness of the Berea grit is included between Nos. 1 and 6 which gives it a total thickness of 39 feet 4 inches. This corresponds with No. 5 of Dr. Newberry's Bedford section which he gave as 45 feet thick and described as "thick-bedded, yellow sandstone with ripple marks."[1] Prof. C. L. Herrick gave the thickness of the Berea grit in his section of the "Cuyahoga Valley and Bed-

[1]Geol. Surv. Ohio, Vol. I, p. 197.

ford" as 45 feet;[1] but it is not stated where the measurement was made and it may not have been at Bedford. Dr. Newberry, however, included in zone No. 5 the two superjacent ones to make the complete Berea formation. These are the "gray shale" from 4 to 6 feet in thickness, No. 4 of his section, which is described above as the Sunbury shale—No. 6 of the writer's section—and the "thin-bedded, yellow sandstone with *Discina Newberryi* and *Lingula melia*," ten feet in thickness, No. 3 of Newberry's section and No. 7 of the above. In the writer's opinion Dr. Newberry was in error in referring Nos. 4 and 3 of his Bedford section to the Berea. The top of No. 5 of the above section has the rough and pitted surface, due to the disintegration of iron pyrites or marcasite, which apparently characterizes the upper surface of the Berea grit in its tortuous distribution entirely across Ohio. No. 4 of Newberry's section is six feet thick above the quarry and is composed of a very argillaceous, thin-bedded shale, mainly gray to bluish-gray in color, but with bands of black shale. This shale the writer correlates with the Sunbury shale of central Ohio, which directly overlies the Berea grit and is generally a rather tough black bituminous shale splitting into thin laminæ; but occasionally in part is soft and gray or bluish-gray in color. This shale is also generally found in the sections in northern Ohio immediately superjacent to the Berea grit, as will be seen later in this bulletin in the description of these higher rocks; although occasionally either the shale or the overlying sandstone zone, which sharply separates it from a still higher but similar shale, is apparently wanting. This shale, or a very similar one, caps the Berea grit in the famous quarries at that town and in 1875 Meek in giving the horizon of *Discina* (*Orbiculoidea*) *newberryi* Hall listed it as from the "Berea shale."[2] This is apparently the first appearance of the term Berea shale in geological literature; but we are not sure that Meek intended to recognize the shale as a stratigraphic unit. Dr. Orton in 1879, however, recognized it as a stratigraphic term and said that "The *Berea shale* needs to be interpolated between the Berea sandstone and the Cuyahoga shale."[3] But it was preoccupied as the name for a geological terrane since Newberry in 1870 published Berea as the name of the subjacent massive grit from the quarries at that town.[4]

In 1878 Professor Hicks applied the name "Sunbury black slate" to this shale from the outcrops on Rattlesnake Creek about two miles east of Sunbury, Delaware County, in central Ohio. In 1879 Dr. Orton correctly correlated the Waverly black shale of southern Ohio with the black shale overlying the Berea grit in the quarries at that town and stated that "No better name could be found for it than Berea shale—for it makes the roof of the Berea quarries, just as it does of the lower

[1]Bull. Geol. Soc. America, Vol. II, p. 40.
[2]Geol. Surv. Ohio, Vol. II, pt. II, Palæontology, explanation of Plate XIV.
[3]Ann. Rept. Secretary of State for 1878 (1879), p. 594.
[4]Geol. Surv. Ohio, Rept. Prog. in 1869, p. 21.

Waverly quarries of Pike County."[1] In another report Dr. Orton in reviewing the correlation of the formations between northern and southern Ohio stated that in order "To make the correlation of the series [Waverly] more exact, one element must be added to Dr. Newberry's section of the group in Northern Ohio. The *Berea shale* needs to be interpolated between the Berea sandstone and the Cuyahoga shale."[2] Later Dr. Orton, judging from the thickness he assigned to his Berea shale in northern Ohio, evidently included in it the sandstone and shale which overlie the Sunbury shale[3] and subsequent writers have generally followed this usage. In 1902 the writer revived the name Sunbury shale for the Waverly black shale[4] which is the first definite geographic name that was not preoccupied, applied to this shale. The Sunbury shale in this quarry is clearly shown in Plate XLVIII where the man is standing on top of the Berea grit and pointing to the line of contact between the Sunbury shale and superjacent sandstone zone.

The formation succeeding the Berea grit was named the Cuyahoga shale by Dr. Newberry in 1870,[5] and described in his reports on the geology of Cuyahoga and Summit counties published in 1873. In the Cuyahoga County report Dr. Newberry stated that the Cuyahoga shale "is the uppermost member of the Waverly group [series], and consists mainly of gray argillaceous shale with thin flags of fine sandstone scattered through it. Its outcrop forms a belt extending from Berea, where it caps the Berea sandstone, around through Parma and Independence into the valley of the Cuyahoga, of which it forms the immediate banks on both sides as far southward as Cuyahoga Falls."[6] Also in the Summit County report he stated that the Cuyahoga shale "is better exhibited in Summit County than in any other part of the state. It has a thickness of from 150 to 200 feet, and has been given the name it bears because it forms the greater part of the banks of the Cuyahoga from Cuyahoga Falls to the north line of the county."[7] Dr. Newberry's lithologic description is not a very accurate one for the lower part of this terrane. Approximately the lower 130 feet of the Cuyahoga in this basin consists mainly of black to bluish-black shale, with the exception of the Aurora sandstone 5 feet or more in thickness near its base. This shale may be followed eastward across northern Ohio to the State line where it apparently agrees with the terrane which was named the Orangeville shale by Dr. I. C. White.[8] This shale was de-

[1]Am. Jour. Sci., 3d ser. Vol. XVIII, p. 138.
[2]Ann. Rept. Secretary of State for 1878 (1879), p. 594.
[3]Geol. Surv. Ohio, Vol. VI, 1888, p. 36 and ibid., Vol. VII, p. 30. In these reports the thickness of the Berea shale is given as from "fifteen to fifty feet;" but probably nowhere in northern Ohio can be found more than from eleven to fifteen feet of the Sunbury shale.
[4]Jour. Geology, Vol. X, p. 262.
[5]Geol. Surv. Ohio, Rept. Prog. in 1869, p. 21.
[6]Geol. Surv. Ohio, Vol. I, p. 185.
[7]Ibid., p. 210.
[8]Second Geol. Surv. Pa., Q^3, 1880, p. 63.

fined by Dr. White as "prevailingly blue, but often rusty or reddish-brown on exposed surfaces, always more or less argillaceous, seldom exhibiting sandy layers more than 6 inches thick; and containing considerable quantities of scattered iron ore balls" with a thickness of about 75 feet at Orangeville. It was stated that the name was used "merely for the convenience of avoiding in this report a premature discussion of the question of its identification with the Waverly black shales of Andrews, or lower member of the Cuyahoga shale of Newberry."[1] The term Waverly black slate was applied by Professor Andrews in 1870 to a black shale in southern Ohio[2] which has since been shown to be the same shale as that which is now called the Sunbury. At Orangeville the Sunbury shale or its horizon is beneath the surface and the base of the shale bank on the Pymatuning Creek is above the horizon of the Aurora sandstone which occurs between these two shales.

The stratigraphic position of the shale on the creek bank in Orangeville was clearly shown from the record of a well drilled in 1901 and 1902 in the creek valley above the State Street bridge in that village. The mouth of this well was estimated to be about 10 feet higher than the base of the shales exposed on the creek bank and the Berea grit was reached at a depth of 42 feet.[3] The Sunbury shale immediately succeeds the Berea grit and the thickness of apparently its equivalent in surface exposures at the two localities nearest Orangeville, which have been studied by the writer, is 14 feet on the bank of the Mahoning River above Warren, Ohio,[4] and probably 14½ feet on Walnut Creek, near Cortland, 12 miles west of Orangeville. This indicates that the base of the shale bank on the Pymatuning Creek at Orangeville is some 18 feet higher stratigraphically than the top of the Sunbury shale, which apparently was not included in Dr. White's original description of the Orangeville shales. In his following report, however, the Orangeville shales were stated to be the "bottom deposits of the *Cuyahoga formation* of Ohio—120 feet thick on the Shenango River at Sharon, 120 feet thick on Cussewago Creek, usually 100 feet throughout Crawford County [Pa.], and in very few places less than 60 feet—are generally dark bluish shales (with a few scattered thin layers of sand), often holding small lenticular nodules of clay-iron stone, but more commonly weathering brown from disseminated iron."[5] In this report Dr. White limited the *top* of the Orangeville shales by the base of the Sharpsville sandstone and their *base* by the top of the Corry sandstone, beneath which are the Cussewago shales and sandstone in northwestern Pennsylvania. It will be shown later in this bulletin that the Corry sandstone and Cussewago shales and sandstone of Pennsylvania are the eastern continuation of the Berea sandstone of Ohio. Dr.

[1]Second Geol. Surv. Pa. Q^3, p. 63.
[2]Geol. Surv. Ohio, Rept. Prog. in Sec. Dist., in [1869], p. 66.
[3]Jour. Geology, Vol. X, 1902, p. 308.
[4]Ibid., p. 301.
[5]Second Geol. Surv. Pa., Q^4, 1881, p. 89.

PLATE XLVIII.

The Sunbury shale and overlying Aurora sandstone above Berea on bank of Tinkers Creek, Bedford.
See pages 415, 417 and 419.

White also apparently cited the exposure of Sunbury shale near Warren, Ohio, as in the Orangeville shales,[1] and referred especially to the abundant fossils near the bottom which is characteristic of the Sunbury shale. From the above account it appears that the Orangeville shales as defined by Dr. White directly succeed the Berea sandstone of Ohio, and extend up to the base of the Sharpsville sandstone of Pennsylvania. This terrane extends from western Pennsylvania to the Cuyahoga Valley and it is probably better to consider it a geologic unit for mapping in northern Ohio, which may be called the Orangeville formation. On this classification the Sunbury shale in northern Ohio becomes the lower member of the Orangeville formation as the writer indicated in 1902,[2] and the other members will be described later in this bulletin.

It is to be remembered that for some years Prof. H. P. Cushing of Western Reserve University has maintained that the Orangeville shale, as above limited, is the lithologic unit which ought to be accepted for mapping in northern Ohio, as he has said to the writer, and as has been reported in the paper last cited.

Prof. C. L. Herrick in his section of the "Cuyahoga Valley and Bedford" reported the "Berea black shale - - - 10-15 ft."[3] between the Berea grit and the "flags and shales" in the lower part of the Cuyahoga shale, using this latter term in the sense employed by Dr. Orton.[4] Judging from the thickness, however, this Berea shale of Herrick would appear to correspond more nearly with the Berea shale of Meek as shown in the quarries at Berea than to the Orangeville formation, which according to Professor Herrick's section is the interval that it fills. The Orangeville formation in the Cuyahoga basin varies from 115 to nearly 130 feet, so that Herrick's estimate of the thickness of this interval is erroneous as given in this section. At the lower end of the Cuyahoga gorge about the upper 15 feet of the shale of the Orangeville formation is shown, which on the weathered bank is similar in appearance to the lower shale under similar conditions, and perhaps Professor Herrick regarded them as identical. It is also not improbable that he may have seen the Aurora sandstone, which overlies the Sunbury shale, at a locality where favorably exposed and mistaken it for the Sharpsville sandstone—the one superjacent to the Orangeville formation.

Finally, No. 3 of Newberry's Bedford section, which he described as "thin-bedded, yellow sandstone" 10 feet thick, is the Aurora sandstone superjacent to the Sunbury shale, 7½ feet of which is shown on the bank above the former quarry in the section above the Pennsylvania Railroad viaduct. This zone forms the upper part of Plate XLVIII and shows the thin-bedded sandstones and layers of shale which compose it.

[1]Ibid., p. 90.
[2]Jour. Geology, Vol. X, p. 312.
[3]Bull. Geol. Soc. America, Vol. II, p. 40.
[4]See ibid., p. 35.

Farther up the creek on its eastern bank and just above the old Bedford Rolling Mills is a section showing the upper terranes of the previous one.

Section above the Old Bedford Rolling Mills.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
3.	*Aurora sandstone*. Gray, fine-grained, thin-bedded sandstone, alternating with layers of shale, the sandstones predominating	7	4	35	--
2.	*Sunbury shale*. Argillaceous shale, splitting into thin laminæ, which are mainly of gray color, but occasionally vary from blackish-gray to black, bituminous shale. At the base, *Lingula melie* Hall (small specimens), and *Orbiculoidea herzeri* Hall and Clarke, occur sparingly	6	--	27	8
1.	*Berea grit*. Some of the upper layers thin-bedded; but lower ones massive, varying from coarse-grained sandstone to grit. Partly covered to creek level and only about the upper half of the formation is exposed	21	8	21	8

Another section still farther up the stream was studied near the upper end of the high banks under the bridge of the A. B. C. Division of the Northern Ohio Traction and Light Company. At this locality the Berea grit forms the floor of the creek and extends up the bank for some feet, but the best exposure of the shale is on the south bank directly beneath the traction bridge.

Section at the A. B. and C. Traction Bridge.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
5.	*Brecksville shale*. Bluish to bluish-gray shale, with an occasional blackish streak, which breaks into very small pieces as weathered, and shown on the upper part of the bank	10	10	51	--
4.	*Aurora sandstone*. Alternating shales and sandstones of bluish-gray color, the sandstones predominating	8	3	40	2
3.	*Sunbury shale*. Thin argillaceous, bluish-gray shales, splitting into small pieces. At the base, a blackish, bituminous shale 1 inch in thickness, which splits into thin, smooth layers, and contains *Lingula melie* Hall. In lithologic ap-				

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
	pearance only the 1 inch of blackish shale at the base of this zone resembles the *Sunbury shale* of central and southern Ohio, and this is not as black as typical Sunbury shale. It is probable, however, that the bluish color and other characters of this zone are a local variation, and that all of it may be correlated with the Sunbury shale. This conclusion is supported by the overlying zone of bluish-gray sandstones and shales which almost invariably succeeds the Sunbury shale..	5	5	31	11
2.	*Berea grit.* Massive, grayish, rather coarse-grained sandstone	21	6	26	6
1.	Shaly to thin-bedded, blue sandstone to creek level, all of which is in the Berea. The sandstone in the bed of the creek shows numerous ripple-marks	5	--	5	--

The last three sections, viz., "at the A. B. and C. Traction Bridge," "above the Bedford Rolling Mills" and "above the Cleveland and Pittsburgh Railroad viaduct" in about the same form as herewith presented, were first published by the writer in 1902 in the Journal of Geology.[1]

The thickness of the formations from the lowest rocks studied on Tinkers Creek to the top of the bank beneath the A. B. and C. Traction bridge is indicated on the following diagrammatic section:

General Section of Formations on Tinkers Creek.

224′		Top of shales below A. B. and C. Traction bridge
	11′—	Brecksville shale
213′+		
	$8\frac{1}{4}$′	Aurora sandstone
$204\frac{5}{6}$′		
	6′	Sunbury shale ($5\frac{1}{2}$ to 6 feet)
$198\frac{5}{6}$′		
	$39\frac{1}{3}$′	Berea grit
$159\frac{1}{2}$′		
	88′	Bedford formation
$71\frac{1}{2}$′—		
	$21\frac{1}{2}$—	Cleveland shale
50′		
	50′	Chagrin formation
0′		As far down creek as studied

[1]Vol. X, pp. 297-299.

Sagamore Creek Sections. — A stream crosses the southwestern and southeastern corners of Bedford and Newburg townships which affords interesting outcrops of the older formations shown on Tinkers Creek. The stream is known as Sagamore or Sogamore Creek; but the former spelling, which is that used by the Lake Erie and Pittsburgh Railroad, has been accepted by the writer. This creek crosses the highway on the eastern side of the Cuyahoga River about one-half mile southeast of Alexander and one and one-fourth miles southeast of where the highway crosses Tinkers Creek.

The lowest outcrops of the Chagrin formation occur 50 feet barometrically higher than the level of the Cuyahoga River bridge at Alexander. These consist of bluish, argillaceous shale containing small, ironstone concretions which occur in somewhat definite layers. About 2 feet above the base of the outcrop is a zone containing a considerable number of specimens of *Liorhynchus ohioense* n. sp.?; a few of *Camarotœchia* and one fragment of a *Spirifer*, probably *S. disjunctus*. The specimens of *Liorhynchus* were fairly abundant in this thin zone and mainly in shale; but an occasional specimen was also found in the small concretions which occur at about the same horizon. A little farther up the bank are cliffs 50 feet or more in height containing occasional layers of thin sandstones which are more conspicuous in the upper half of the cliff.

Farther up the stream, on its southern bank and about 90 feet higher (barometrically) than the lowest outcrops of the Chagrin formation, is its contact with the Cleveland shale. At this locality is a steep bank, about the lower 45 feet of which belongs in the Chagrin formation, capped by some 15 feet of Cleveland shale; but not showing the entire thickness of the latter. One foot nine inches above the base of the Cleveland shale is a 6-inch zone of bluish sandstone and shale with the lithologic characters of the Chagrin. The thin sandstone is at the base of this zone and is about $1\frac{1}{4}$ inches thick. Just above this cliff on the bank of the creek, forming its floor in high water, is a fossiliferous zone in which are abundant specimens of *Liorhynchus* n. sp., where in fact the specimens of this species occur in immense numbers. In addition to the *Liorhynchus*, specimens of *Grammysia*, *Camarotœchia* and *Lingula* occur.

Farther up the creek, on the opposite side, is a steep bank, on which the entire thickness of the Cleveland shale is shown, which has furnished the following section:

No.		Thickness. Feet.	Total thickness. Feet.
7.	*Sagamore lentil of Bedford formation.* Massive, bluish-gray, rather fine-grained sandstone, which weathers to a buff color	3	100
6.	Thinner bedded, bluish sandstone, alternating with shale	6±	97

No.		Thickness. Feet.	Total thickness. Feet.
5.	Mainly bluish, argillaceous shales, with thin layers of sandstone	21	91
4.	Sandstone stratum, 4+ inches thick, with fossils in its upper part	$\frac{1}{3}$+	70
3.	Mainly bluish shale, with thin layers of sandstone	$3\frac{1}{2}$	$69\frac{1}{2}$
2.	*Cleveland shale*, black and bituminous	26	66
1.	*Chagrin formation* to creek level	40	40

In loose blocks in the creek at the foot of the above section were specimens of *Spirifer disjunctus* Sowb., *Athyris*, *Camarotœchia* and *Liorhynchus*, all of which were associated in the same block from the upper part of the Chagrin formation.

The above section gives 26 feet for the entire thickness of the Cleveland shale, both limits of which are shown, together with the lower 34 feet of the Bedford formation. It is thought best to regard the base of No. 7 as the base of the sandstone zone, although there are some thinner bedded sandstones in the subjacent zone. This gives 31 feet from the base of the sandstone lentil to the top of the Cleveland shale, which is some ten feet less than the thickness of the corresponding interval on Tinkers Creek, some $3\frac{1}{4}$ miles to the northeast. This difference in the thickness of that portion of the formation below the sandstone zone is probably due to its lenticular shape and shows an earlier invasion of the sandy deposits on Sagamore than Tinkers Creek.

A gully on the southern bank of Sagamore Creek only a few rods below the embankment of the Lake Erie and Pittsburgh Railroad afforded the following section of continuous rock exposures:

Section on Sagamore Creek Below Railroad Culvert.

No.		Thickness. Feet.	Total thickness. Feet.
10.	*Sagamore lentil of Bedford formation.* Bluish to buff sandstone, alternating with blue shale. Sandstone ripple-marked	16	90−
9.	Thick, massive sandstone	$1\frac{3}{4}$	$73\frac{3}{4}$
8.	Shale, alternating with thin sandstones	1	72
7.	Lowest thick sandstone, very compact, blue, and slightly calcareous, with ripple-marks on the upper surface. *Base of Sagamore lentil*	$\frac{3}{4}$	71+
6.	Bluish, argillaceous and arenaceous shales, alternating with thin layers of bluish sandstone an inch or a little more in thickness	$24\frac{5}{6}$	$70\frac{1}{3}$
5.	Compact, calcareous sandstone, 5–7 inches thick, with iron pyrite in upper part, and the lower two inches the most calcareous	$\frac{1}{2}$±	$45\frac{1}{2}$
4.	Mainly bluish, argillaceous shale, with an occasional sandy layer	$3\frac{5}{6}$	45

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Cleveland shale.* All compact, dense, massive, black shale as shown in the gully	23	$41\frac{1}{6}$
2.	*Chagrin formation.* Soft, bluish, argillaceous shale	$3\frac{2}{3}$	$18\frac{1}{6}$
1.	Alluvial deposit to level of Sagamore Creek	$14\frac{1}{2}$	$14\frac{1}{2}$

In the above section from the top of the Cleveland shale to what was called the base of the Sagamore lentil is 29+ feet, overlying which is $19\frac{1}{2}$ feet of the Sagamore sandstone without reaching the top of the lentil.

On the northern side of the creek, only a short distance below the railroad culvert, is a steep bank on which is shown the entire thickness of the Cleveland shale as well as that of the lower shaly part of the Bedford formation. This section was leveled by Mr. Morse, who obtained the following thickness for the several intervals:

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Sagamore lentil of the Bedford formation.* Bluish-gray sandstone, separated by some layers of bluish shale to thin sandstone; estimated that 10 to 15 feet caps the top of this cliff	10+	77+
3.	Mostly bluish to bluish-gray shale, with thin layers of bluish sandstone. Almost at the base apparently the dorsal valve of *Syringothyris*	$28\frac{1}{2}$	67+
2.	*Cleveland shale*	26	$38\frac{2}{3}$
1.	*Chagrin formation* to level of creek; but the rocks are partly concealed	$12\frac{2}{3}$	$12\frac{2}{3}$

The last two sections are on opposite sides of the creek and only a few rods apart. It will be noticed that the thickness of the lower shaly portion of the Bedford formation is in close agreement in the two sections, viz., $28\frac{1}{2}$ feet on the northern bank and 29+ feet on the southern as leveled by the writer. The thickness of the Cleveland shale is not so uniform, since 26 feet was obtained on the northern bank and but 23 feet on the southern.

On the northern bank, just above the railroad culvert, a quarry had been opened for the railroad, which in June, 1907, furnished the following section:

No.		Thickness. Feet.	Total thickness. Feet.
5.	Layers of blue sandstone, alternating with arenaceous shales and thin sandstones. The good sandstone varying from 6 inches to a foot in thickness. The sandstone layers frequently thin out or become concretionary, even the subjacent 2-foot layer. There are also contorted layers, and in general this sandstone does not appear to be a very desirable quarry stone	16	20
4.	Blue, fine-grained sandstone near foot of quarry wall	2	4

No.		Thickness. Feet.	Total thickness. Feet.
3.	Blue shale	$1\frac{1}{3}$	2
2.	Sandstone	$\frac{2}{3}$	$\frac{2}{3}$
1.	Blue shale; but this lower part of the bank was mainly concealed by debris		

The barometer made the floor of this quarry 30 feet higher than the top of the Cleveland shale on the bank below the railroad culvert, and it will be remembered that on this lower bank the thickness of the lower shaly portion of the Bedford by level is $28\frac{1}{2}$ feet. It, therefore, appears that the sandstone at the base of this quarry is at the base of the Sagamore sandstone and all of the superjacent rock belongs in this lentil. This interpretation is supported by the section in the gully on the southern side of the creek in which the lowest sandstone layer of this lentil is 9 inches thick (8 inches in this section), then a zone of shale and thin sandstones 1 foot thick (shale zone of 1 foot 4 inches in this section), and then a massive sandstone 1 foot 9 inches thick which is apparently represented by the 2-foot sandstone in this section. It will also be seen from the description of the next section that the top of this quarry and bank nearly reaches to the top of this sandstone lentil.

On the opposite side of the creek and a little farther up stream the railroad has opened another quarry which gave the following section:

Section on Sagamore Creek above Railroad Culvert.

No.		Thickness. Feet.	Total thickness. Feet.
7.	*Bedford formation.* Shale and shaly sandstone to the top of the bank in alternating zones, and none of the sandstone more than 4 or 5 inches thick. Not measured, but estimated as about 10 feet in thickness	10±	32
6.	*Sagamore lentil of Bedford formation.* Rather irregular layers of bluish to buff, fine-grained sandstone, some of which show ripple-marks, separated by layers of bluish shale, and shaly sandstone. There are also some concretionary layers	$16\frac{1}{4}$	22
5.	Fine-grained, bluish sandstone, with shale partings of variable thickness	$1\frac{3}{4}$	$5\frac{3}{4}$
4.	Massive layer of sandstone from 24 to 25 inches thick	2	4
3.	Shale zone	$1\frac{1}{6}$	2
2.	Sandstone layer and bottom of *Sagamore lentil*	$\frac{5}{6}$	$\frac{5}{6}$
1.	Blue shale; but lower part of bank covered by debris		

A view of the bank showing the Sagamore lentil and overlying shale described in the preceding section is shown in Plate XLIX, in which Mr. Morse is marking the top of the 2-foot sandstone layer No. 4 of the section.

It will be seen in the above section that the lower three zones of

the quarry correspond very closely in thickness with those in the quarry just above the railroad culvert as well as with the lower three zones of the sandstone lentil in the gully on the southern side of the creek just below the railroad embankment. It is thought that in the three sections they represent the same stratigraphic horizon, and the base of the lowest sandstone is regarded as marking the base of this sandstone lentil. Its upper limit is clearly shown and well marked in the upper railroad quarry where the sandstones are succeeded by rocks in which shales predominate. In this quarry the thickness of the sandstone zone is 22 feet, and on account of its typical outcrops on this creek it has been named from it the Sagamore lentil. The writer's attention was first called to this sandstone as shown in Sagamore Creek and vicinity by Prof. H. P. Cushing, who stated at that time that it was stratigraphically higher than the sandstone lentil found at Euclid and other quarries in the immediate vicinity of Cleveland.

As already stated the base of the sandstone lentil on Sagamore Creek is stratigraphically lower than that of the one on Tinkers Creek, the former about 29 feet above the top of the Cleveland shale and the latter about 41 feet; but the thickness in both creeks is apparently the same or 22 feet. Since the sandstones partly overlap stratigraphically it is thought best to use the same name for them at both localities.

Farther up the stream on its northern bank and above the upper quarry, is a fine exposure of the lower shales of the Bedford formation. Still farther up the stream and continuing above the first north and south highway is the Sagamore sandstone lentil which in this part of the stream forms its floor and bank.

The thickness of the entire Bedford formation was not accurately learned. On the north and south road, on the hill to the south of the creek are outcrops of the Berea grit; but it is not certain that its base is shown. From this outcrop, however, down to the top of the Cleveland shale on the bank of the creek below the upper quarry the barometer gave 85 feet. The apparent base of the Berea grit is also shown on the east and west highway which lies to the north of the creek, and the barometer gave 70 feet from this outcrop to the base of the Sagamore sandstone in the upper railroad quarry. If to this the $28\frac{1}{2}$ or 29 feet of the lower shale be added, it will give about 99 feet for the apparent thickness of the Bedford formation. Again, the base of the Berea grit is shown in the railroad cut to the south of Sagamore Creek. The average of two readings of the barometer made the base of the Berea in this cut $42\frac{1}{2}$ feet higher than the top outcrop of the Sagamore sandstone in the gully near the railroad culvert and just west of the embankment. If to this be added the $48\frac{1}{2}$ feet of rock down to the top of the Cleveland shale it will give 91 feet for the thickness of the Bedford formation. These thicknesses of 99, 85 and 91 feet indicate that the Bedford formation in this vicinity has probably a thickness of some 90 feet or more.

PLATE XLIX.

The Sagamore lentil of Bedford formation and superjacent shale above railroad culvert on Sagamore Creek. Mr. Morse marking top of 2-foot course. See page 425.

As just stated, the contact of the Bedford formation and Berea grit was clearly shown in the first Lake Erie and Pittsburgh Railroad cut to the south of the culvert over Sagamore Creek when the road was in process of construction. The upper part of the Bedford formation in this cut consists of a fissile, rather soft blue or chocolate colored shale. In the main it is apparently blue shale; but there are portions which are of decided chocolate color. The latter are apparently local portions that have been reddened and not any definite zone in the upper part of the formation. At the base of the Berea in this cut is generally a rather massive layer and then the higher rock is mainly thin-bedded, much of it not more than 1 or 2 inches in thickness and strongly cross-bedded as shown in Plate L, A. There is perhaps 12 feet of the sandstone shown in the cut where it is thickest; but in some parts the Bedford extends so high that only a few feet of the Berea appears. The contact of the Bedford and Berea formations is an irregular one as was shown for some distance along this cut. This structure shows unconformity by erosion and the contact of the two formations and line of disconformity is seen in Plate L, B, as it appeared in 1907 during the construction of the railroad. This break in the continuity of deposition and uneven surface of the Bedford indicates an elevation of the sea bottom on which the Bedford sediments were deposited until the sea became very shallow or perhaps its bottom was raised to a land surface. It is perhaps an open question whether this disconformity represents any considerable time interval between the deposition of the two formations or not. The evidence, however, at some other localities where the contact of these two formations occurs appears to the writer to indicate that the disconformity does represent more than an inconsiderable period of time.

The evidence favoring a line of disconformity between the Bedford and Berea is not confined to their contact in this railroad cut or the vicinity of Cleveland; but has been noticed at various localities in northern and central Ohio, some of which will be described in other portions of this bulletin.

Disconformity is used as defined by Dr. Grabau "to cover unconformable relation of strata where no discordance of dip exists."[1] For this type of unconformity Professor Crosby has recently proposed the name *para-unconformity.*[2]

The irregular surface of the Bedford shale was noted by Dr. Newberry who stated that "In most localities where the Bedford shale is exposed, the upper surface is very irregular, and it is evident that this formation has been extensively eroded by the agency which transported the beds of sand now consolidated into the Berea grit. It is probably

[1]Science, N. S., Vol. XXIX, May 7, 1909, p. 750. This term was first proposed by Dr. Grabau in 1905 in Science, Vol. XXII, Oct. 27, p. 534.

[2]Jour. Geol., Vol. XX, 1912, p. 296.

due to this fact that the red shale is so frequently found to be wanting in the section."[1] Preceding this excerpt under the description of the Bedford shale Dr. Newberry reported that in northern Ohio it consists of "seventy to seventy-five feet of argillaceous shale, of which the upper portion is generally of a marked red color, while the lower portion is dark bluish gray." It is obvious from the above excerpts that Dr. Newberry's idea of the reason for the non-appearance of the red shale in some localities was because it had been eroded before or in connection with the deposition of the Berea sands.

Dr. Orton also considered the conditions under which the Bedford and Berea formations had been deposited and wrote as follows:

"A very marked change in the geography of Ohio took place during the Bedford and Berea epochs. The western half of the State was mainly converted into dry land by the great extension of the Cincinnati axis, and both of the formations named above are *shore deposits*. They carry the proofs of this origin in unmistakable characters. They are ripple marked from [one] end of the State to the other, and mud casts and worm burrows abound, especially in the Bedford shale."[2]

It appears to the writer that these erosion channels belong in the division termed "superficial" by Dr. Ulrich which he states "embraces all subaerial channels formed by running water, including tidal overflows." The other two classes are called "submarine" and "subterranean." The submarine are stated to embrace "all channels produced by currents scouring the sea bottom; [but] these are very rare as strong currents manifestly seldom occur in the shallower epicontinental seas." The subterranean class "includes solution cavities and caverns formed in limestones and dolomites by the action of acidulated surface waters."[3] It is obvious that these channels do not belong in the third class of the above classification and it also appears to the writer that evidence in some of the localities also excludes them from the second or submarine. According to the reasoning of some geologists this unconformability and coarse material of the Berea would be considered as indicating a new cycle of deposition in a new time period and would be considered as evidence in favor of regarding the contact of the Bedford and Berea formations as the line of division between the Devonian and Carboniferous systems.

Chippewa Creek Sections.—Cuts on the Cleveland Terminal and Valley Railroad (Baltimore and Ohio) both above and below Brecksville station show very well the upper part of the Chagrin shales. The one just below the station is the better where 56 feet of rock is shown composed principally of blue somewhat gritty, argillaceous shale which weathers into a light blue and very fine shale on the face of the cliff. In the upper part of

[1]Geol. Surv. Ohio, Vol. II, 1874, p. 91.
[2]Ann. Rept. Secretary of State for 1879 (1880), p. 599.
[3]Science, N. S., Vol. XXX, Dec. 31, 1909, p. 973.

A.—Cross-bedding in lower part of Berea sandstone, in Lake Erie and Pittsburgh Railroad cut south of Sagamore Creek. See page 427.

B.—Disconformity between Bedford and Berea formations as formerly shown in Lake Erie and Pittsburgh Railroad cut south of Sagamore Creek. See page 427.

the cut the surface of some of the layers as weathered is brownish from the iron. There is an occasional layer a little thicker and also the slightly calcareous concretions which weather to a rusty color; but in the main the bank is a mass of fine argillaceous shale.

On the opposite bank of the river and a little farther north is a rather steep cliff, the lower portion evidently the Chagrin shale, while the upper part is apparently tougher and probably is the lower part of the Cleveland shale.

Chippewa Creek crosses Brecksville Township along its middle portion from west to east and enters the Cuyahoga River a little south of Brecksville station about $9\frac{1}{4}$ miles east of south of Newburg Falls. The mouth of the creek is about $4\frac{1}{4}$ miles southeast of the Independence quarry at South Park and $5\frac{1}{2}$ miles southwest of the glen on Tinkers Creek at Bedford. The lower course of the stream is cut out of the soft Chagrin shales; but above this formation, through the Cleveland shale and Bedford formation to the base of the Berea grit under the highway bridge below and east of Brecksville, it has cut a deep gorge which is wild and rugged. In this part of its course the stream has a rapid descent and immense loose blocks of Berea grit lie in the channel which render it laborious to follow and the bed rocks are also largely concealed by the alluvial deposits and large boulders. The gorge is rather narrow through the Berea grit, but the banks are not high again until more than one-half mile above Brecksville when the creek is bordered for one and one-half miles or more by the Orangeville formation, which in turn is overlain by thin-bedded sandstones and shales. This is an interesting stream on which part of the formations above enumerated are excellently shown and one well worthy of study.

The shale banks on the lower part of Chippewa Creek which are neither continuous nor high are in the upper part of the Chagrin formation with about the same lithologic character as in the railroad cut which has already been described. Toward the top of the shale it is rather fossiliferous and the best locality known for collecting in this formation in the Cleveland region is in the bed of this creek about half way from its mouth to Brecksville. It is opposite a high shale cliff, the lower 20 feet of which belongs in the Chagrin while above is the tougher Cleveland shale, the line of contact being sharply marked on the bank. This cliff is in plain sight from the highway leading from Brecksville station to Brecksville, a short distance west of the house of Mr. C. H. Miller and about midway between the railroad station and village. The best place for collecting is in the bed of the creek where the fossils occur most abundantly in the bluish, soft shales, although the harder layers are also fossiliferous. The fossils break badly in the soft shales, but a considerable fauna may be obtained providing care is exercised in collecting and packing them. The very fossiliferous horizon in the bed of the creek on the northern side is about opposite

the upper end of the cliff and some 20 feet below the base of the Cleveland shale; but some fossils were found in both the shales and concretions nearly as high as the top of the formation. A little farther up the stream than the very fossiliferous locality already described and on the same side of it, but a little higher stratigraphically, in certain layers fossils are fairly abundant, especially *Dalmanella tioga* (Hall) Wms. The calcareo-ferruginous concretions also contain a number of specimens, particularly of *Spirifer disjunctus* Sowb. and *Dalmanella tioga* (Hall) Wms. The Spirifers, however, are not so abundant as in the lower locality. The soft shales also contain specimens of *Cyrtia alta* Hall, although generally they are badly crushed and broken. The following species have been identified from this locality, all of which were obtained in about an hour's time:

1. Spirifer disjunctus Sowb. -- (a)

There are New York Chemung specimens preserving the thin shells, and having plications of similar strength to those of these specimens. The hinge area of the ventral valve is preserved, showing that it is not high, so that the specimens do not belong to *Cyrtia alta* Hall or to *Syringothyris*, while the sinus and fold both show very distinct plications, some 12 or more in number. Specimens on which the shell is well preserved show fine concentric striæ, as given by Hall in his description of the species, while one of the best preserved exteriors shows small and rather numerous pustules. The form so identified and figured by Herrick (Geol. Surv. Ohio, Vol. VII, pl. 23, fig. 11) can be duplicated from the specimens collected at this locality. Specimens from Chippewa Creek and other Chagrin localities in Ohio, were compared with authentic specimens of this species in the large Devonian collections at Cornell University. It was noted that the hinge area is not so high as in part of the New York specimens; but is fully as high as on specimens of this species from France. Specimens from Chautauqua Creek, below Summerdale, Chautauqua Co., N. Y., the southwestern county of New York state, which are identified as *S. disjunctus* by Professor Williams, do not have much higher hinge area on the ventral valve than the Ohio ones, and many of them are rather narrow, like those from Ohio. The Summerdale specimens have from 8—12 plications on fold and sinus which have about the same strength as those on the specimens from Ohio. The Chippewa specimens are similar to, though narrower than, others from Meadville, Pa., labeled *Sp. disjunctus* by Dr. Kindle, which identification is accepted by Professor Williams. Chippewa Creek specimens were shown to Professor Williams, who accepted their identification as *S. disjunctus*. He stated that the narrow, non-mucronate form is characteristic of the western specimens; which is the character of the abundant ones on Chautauqua Creek

in southwestern New York. Professor Williams also said that the pustules indicate the rather later forms of this species; although he considers them of generic, rather than specific value, and says that they may be expected on any species that is well enough preserved.

In the New York State Museum, the slab containing the original of fig. 19, pl. 42 (Vol. IV, Pal., N. Y.), which is from Meadville, Pa., was studied, and associated with that specimen is a number of other impressions of this species which are not mucronate; but similar to the more usual forms. There is no question but that specimens from Chippewa and Brandywine creeks, Cherry Township and other localities in Ohio, which were compared with authentic specimens of *Spirifer disjunctus*, belong to that species.

2. Dalmanella tioga (Hall) Wms.________________________________ (a)

Specimens from the Erie shale at Le Roy, Lake Co., Ohio, were identified as this species by Whitfield, who stated that "The specimens are somewhat smaller than the general run of the New York Chemung specimens, but otherwise cannot be distinguished from them" (Geol. Surv. Ohio, Vol. VII, p. 453). The Chippewa specimens have the characters which Whitfield gave as characterizing those from Le Roy, and they agree closely with his figure of them (pl. 8, fig. 3). Comparison of Ohio specimens, with figures of the New York species showed that the length of those from Ohio is a little greater in proportion to the width than that of those from New York.

Specimens from Chippewa Creek agree perfectly with specimens from Hornellsville, New York, identified and published by Professor Williams as this species, on p. 80, Bull. 41, U. S. Geol. Survey. The Ohio specimens are probably smaller than the majority of the New York ones; but the former are larger than part of the Hornellsville ones. The radiating lines (striæ)[1] bifurcate and curve upward on the hinge line in the same way in the specimens from both states. The smaller size may be characteristic of the western forms of the species. It was noted, however, that the Ohio specimens are twice the size of those identified and published as this species by Professor Williams, from the Shean excavation above Caneadea, N. Y. (Bull. 41, p. 76, list 481 A).

Dalmanella leonensis (Hall) Hall and Clarke, with which Ohio specimens might possibly be compared, is a much smaller species, with finer lines (striæ) as shown by comparison with specimens from South Cuba, N. Y., which were identified and published as this species by Professor Williams (U. S. Geol. Survey, Bull. 41, p. 67, list 477 E^5).

In the New York State Museum, the original of fig.

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[1]Professor Williams has proposed to use the term lines for elevated linear markings and restrict the use of striæ to narrow grooves depressed below the surface (Proc. U. S. Nat. Mus., Vol. 34, April, 1908, p. 47).

23, pl. 8, Vol. IV, Pal. N. Y., which is a dorsal valve, was examined, and the Chippewa Creek specimens agree with it almost exactly in size, outline, depth and size of sinus, and strength of radiating lines (striæ). There seems to be no question concerning the correctness of the identification of the Ohio specimens with this Chemung species.

Since the above comparisons and notes were made, Professor Williams' revision of "The Dalmanellas of the Chemung Formation" has been published. When the writer was comparing the Ohio specimens with those of the U. S. Geological Survey and Cornell Museum at Cornell in December, 1906, Professor Williams made no mention of this work or the changes in specific reference that appear in it. In this article the old species *Orthis tioga* Hall is divided and figures 20, 22, 29 and 24 of Hall's illustrations on pl. 8, Vol. IV, Pal. N. Y., are referred to *Dalmanella tioga* Hall, sensu stricto, while figures 21, 26, 27, and 28 of Hall are referred to *D. elmira*, which is a new species described by Professor Williams.[1] The difference between these two forms, or species as Professor Williams considers them, appears to be largely in the proportion of length to width. Hall described *O. tioga* as "about two-thirds as long as wide" which is accepted for *D. tioga*, sensu stricto, by Professor Williams, while he states that the other form or species, *D. elmira*, differs from the former "by its subquadrate form; the length is from four-fifths to five-sixths the width." The dimensions of certain specimens of *D. tioga* are given by Professor Williams; certain figures of *D. elmira* were measured as well as some of the specimens from Chippewa Creek and the results are shown in the table below:

D. tioga		*D. elmira*		Chippewa Creek Specimens	
Length.	**Width.**	**Length.**	**Width.**	**Length.**	**Width.**
		fig.6			
14.9 mm.	22 mm.	17.7 mm.	22 mm.	17.2 mm.	22 mm.
		fig. 13		17 +mm.	21.4 mm.
16 mm.	25.5 mm.	16.7 mm.	21.4 mm.	16 mm.	19 mm.
		fig. 11			
14.3 mm.	21.3 mm.	14.3 mm.	19.4 mm.	14.3 mm.	17 mm.

A comparison of the above figures will readily show that in the Chippewa Creek specimens the length is about four-fifths or five-sixths of the width and that the dimensions agree more closely with those of *D elmira* than *D. tioga*. It is believed that these Ohio specimens agree better with the subquadrate form (*D. elmira*) than with the more elliptical one which is the *D. tioga* as restricted by Williams. He states that *D. elmira* occurs in the lower part of the Chemung associated with *D. tioga*, but in the middle and upper part of the Cayuta member *D.*

[1]Ibid., pp. 55, 56.

elmira becomes the prevailing species. The Chemung formation of southern-central New York is divided by Professor Williams in ascending order into the Cayuta shale member and the Wellsburg sandstone member. It appears to the writer that the differences between these two forms are too slight to be considered of specific rank and since their acceptance by other paleontologists has not been noted, he is inclined to list the Ohio specimens under the name *D. tioga.* Perhaps the difference between these two forms is great enough so that it might be better to call the Ohio specimens *D. tioga* (Hall) var. *elmira* Wms.

Professor Williams states that fig. 23, pl. 8, Vol. IV, Pal. N. Y., which is the representation of the type specimens studied by the writer in the New York State Museum, is typical of Hall's original description of *Orthis tioga.* Professor Williams refers this figure to what he calls "form delta;"[1] but it is not clear to what species it is referred since it is not cited under either *D. tioga* or *D. elmira* or apparently any of the other species. The figure, however, has a length of 17.1 mm. and a width of 13.3 mm. so that the length is almost four fifths of the width and on that basis it agrees with the description of *D. elmira.* This conclusion is also in harmony with the reference of the Ohio specimens after a study of Williams' paper since it is concluded that they agree with the form of the original *Orthis tioga* which he calls *D. elmira,* while the comparison of specimens in the State Museum showed that some of the Ohio ones were almost the exact counterpart of the original of fig. 23, pl. 8, Vol. IV.

3. Camarotœchia contracta Hall .... (c)

Some specimens agree closely with descriptions of the New York specimens of this species. The number of plications on each valve, 16–20, is the same, of which the dorsal valve has 4 median ones, which start as two near the beak, and the middle two are the stronger, while the ventral valve has 3 or 4 in the sinus. The specimens of *C. contracta,* in the Cornell University Museum, as well as others from near Olean, N. Y., identified and published as this species by Professor Williams (Bull. 41, p. 96), are less rotund than the Ohio forms. Perhaps specimens from Chippewa Creek more nearly approach those at Cornell, labeled *C. contracta,* than do any of the other Ohio ones; but there is in general a more elongated outline to the New York specimens in that collection.

At the New York State Museum, the original of figs. 34 and 35, pl. 55, Vol. IV, Pal. N. Y., from Horse Corners, Cattaraugus Co., N. Y., was studied, which has 4 plications on the fold, 3 in the sinus and 7 on each lateral margin. Specimens from Chippewa Creek have 4 rather angular plications on the fold, 3 or 4 in the sinus, and usually 6 or 7 on each lateral margin, and occasionally 8. The original of fig. 27, pl. 55, from Bradford, Pa., is a dorsal valve, with 4 angular plications on the fold and 4

[1]Ibid., p. 54.

on each margin. There are other specimens on the same block, which have 3 plications on the fold, and in the sinus they vary in number from 2–4, but the majority have 3.

The Ohio specimens from the shales resemble more closely *C. contracta* Hall than *C. orbicularis* Hall, although the larger ones from the calcareous layers approach the smaller ones of *C. orbicularis*. It is to be remembered, however, that Professor Hall wrote that *C. orbicularis* "presents many of the characters of the larger and more robust forms of *R. contracta*" (Pal. N. Y., Vol. IV, p. 352). It is to be noted that the plications on the fold of the Ohio specimens divide in the same way as those of the typical New York ones of *C. contracta*, leaving the central two the stronger. Those from Ohio are perhaps a little more orbicular in outline than New York specimens of *C. contracta*; but not much more so than the ones of this species from Bradford, Pa. It appears clear to the writer, that these flat and medium sized Ohio specimens from the Chagrin shales may be referred to *C. contracta*.

4. Camarotœchia cf. horsfordi Hall .... (c)

Small specimens, which are badly crushed; but have fine plications like those of authentic specimens of *C. horsfordi*, in the American Museum, from the Hamilton formation at Pavilion, N. Y. The Ohio and New York specimens have 6 or 7 angular plications on the fold or sinus, with 7 or more on each side. This species is generally regarded as confined to the Marcellus and Hamilton formations; but Professor Williams listed specimens from the Chemung, near Caneadea, N. Y., as "like *R. horsfordi*, broad" (Bull. 41, p. 76). These forms were at first compared with *C. stephani* Hall and *C. eximia* Hall; but after specimens of these two species from the Ithaca formation were studied in the Cornell Museum, it was decided, that although the Ohio specimens resemble them in a good many characters, still there was hesitation in referring them to either species. The Ohio forms, with the coarser plications, in general, are hardly so angular (narrow and pointed) as typical ones of *C. stephani*, and yet, on the cards of this species in the Cornell Museum, are numerous specimens of the smaller forms, which are apparently as rotund as *C. eximia*.

In the New York State Museum, the original of figs. 11 and 12, pl. 55, Pal. N. Y., from Bedford, Pa., was examined; it has 7 plications on the fold and 9 on each lateral margin. The original of figs. 13–15, from the same locality, also in this Museum, has 6 plications on the dorsal fold, with 7 on the right lateral margin, and 10 on the left. Both specimens are dorsal valves. These are apparently more gibbous than the Ithaca ones, and there are none of the Ohio specimens as gibbous, with as conspicuous dorsal fold as these two from Pennsylvania.

5. Camarotœchia cf. orbicularis Hall ---------------------------- (rr)
6. Athyris polita Hall -- (c)

In size and general characters, these specimens agree fairly well with the description of this species. The fine, close, concentric lines are well shown on specimens preserving the shell and some show faint radiating lines (striæ) as called for in the specific description.

In the New York State Museum, internal impressions of the ventral valve of this species from Randolph, Cattaraugus Co., N. Y., which are on the same block as the dorsal valve, represented by fig. 31, pl. 47, Vol. IV, Pal. N. Y., very closely resemble internal impressions from the calcareous layer in Chippewa Creek. There are heavy concentric furrows toward the ventral margin of the Ohio specimens which do not occur on those from Randolph; but the impression of a ventral valve of another New York type (fig. 33, pl. 47) shows them as strongly as any of the Ohio specimens. (They are stronger on the New York specimen than the figure indicates.) Specimens were shown Dr. Rudolf Ruedemann, who considered those from the hard, calcareous layer as belonging to this species; but was not so certain concerning the crushed ones from the shale until informed that they were from the same locality.

A. angelica Hall is another Chemung species of New York; but the specimens at Cornell University from southwest of Olean, N. Y., identified and published by Professor Williams as this species (Bull. 41, pl. 96) are mostly rather small, the larger ones, however, are broader in proportion to length than the Ohio specimens, which is in harmony with the figures of the New York types. Dr. Ruedemann considers that the normal form of *A. angelica* is broader than *A. polita* or the Ohio specimens which are here referred to the latter species. Specimens of this species (No. 33,638) labeled *Seminula polita* (Hall) are in the National Museum in Washington, from the rocks at Union City, Pa., which are referred to the Chemung formation.

7. Productella hirsuta Hall ------------------------------------ (rr)

The specimen was compared with types in the American Museum, with which it closely agrees.

8. Liorhynchus sp. -- (rr)

Imperfectly preserved; but probably belongs to *L. mesacostale* Hall.

9. Lingula cf. complanata Wms. -------------------------------- (rr)

Specimen broken about the beak.

10. Cyrtia alta Hall -- (r)

The specimens collected by the writer from the soft shales were badly crushed and broken, although the high hinge area and some other characters showed apparently the correctness of this identification.

In the collections of Adelbert College, Cleveland, are well preserved specimens of this species from this locality, so that there can be no question as to its presence in the upper Chagrin of Chippewa Creek.

11. Grammysia cf. subarcuata Hall .... (rr)
    Imperfect specimen.

At a later time Mr. Clyde R. Miller collected the following species at the locality where the former collections were made:

1. Spirifer disjunctus Sowb. .... (c)
2. Dalmanella tioga (Hall) Wms. var. elmira Wms. .... (a)
3. Liorhynchus mesicostale Hall .... (r)
4. Camarotœchia orbicularis Hall................................. (r)

A little farther up stream than where former collections were made, and a little higher stratigraphically, the following species were collected:

1. Spirifer disjunctus Sowb. .... (a)
2. Dalmanella tioga (Hall) Wms. var. elmira Wms. .... (a)
3. Camarotœchia contracta Hall .... (c)
4. Camarotœchia orbicularis Hall .... (a)
   The majority of the specimens approach this species and it is thought they are nearer it than any other. Part of them are not so broad as the typical figures of this species and in some characters they approach *C. contracta* H. In fact there are specimens that appear to be more or less intermediate between these two species and that it is difficult to refer to either one.
5. Cyrtia alta Hall .... (rr)
6. Athyris polita Hall .... (c)
7. Liorhynchus mesicostale Hall .... (c)
   It is possible that these specimens are crushed ones of *L. globuliforme* (Van.) Hall var. *chagrinanum* which have been flattened in the shale.
8. Liorhynchus globuliforme (Van.) Hall var. chagrinanum n. var. (rr)
9. Productella lachrymosa (Con.) Hall .... (r)
10. Ambocœlia umbonata (Con.) Hall var. gregaria Hall........... (rr)
11. Lingula sp.. (rr)
12. Sphenotus clavulus Hall (?) .... (r)
13. Grammysia communis Hall (?) .... (r)
14. Goniatites sp. or possibly Euomphalus sp. .... (rr)

In the above fauna specimens of *Spirifer disjunctus, Dalmanella tioga, Athyris polita* and *Camarotœchia contracta* occur the most frequently, so that the first two species are listed as abundant and the last two as common. Consequently it appears to the writer that the geologic occurrence of these species in the standard Devonian section of New York is of decided importance in determining the age of the upper portion of the Chagrin formation.

Spirifer disjunctus is listed by Schuchert as only Chemung[1] and it is given as one of the diagnostic Chemung species by H. S. Williams.[2]

[1]Bull. U. S. Geol. Survey, No. 87, 1897, p. 387.
[2]Ibid., No. 210, 1903, pp. 83-88, and No. 244, 1905, p. 57.

This species has generally been considered a very characteristic one of the Chemung in America and also of the upper Devonian in Europe and other portions of the world, where it is frequently reported under the name of *S. verneuili* Murch. It is true, however, that it has been identified by Dr. John M. Clarke and Mr. Charles Butts in rocks of the Olean quadrangle in southwestern New York which they consider as of Subcarbonic [Mississippian] age.[1]

Dalmanella tioga is listed as one of the diagnostic Chemung species by Professor Williams who states "that this species does not occur in the New York sections until the Chemung fauna enters that province, thus marking the transition between the Nunda (Portage) formation and the Chemung. This conclusion, which is founded on evidence furnished by numerous sections exhibiting continuous strata across the transition, causes the Erie shale of Leroy, Ohio, to be assigned to a horizon as high as the Chemung of New York, rather than in the Nunda (Portage). No trace of this species has been reported, so far as the writer is aware, from the Ithaca member or any equivalent horizon. Hence the species may be regarded as diagnostic of the Chemung formation, and not of the Nunda (Portage)."[2] The argument concerning the age of the rocks containing these specimens will not be changed if part or all of them are referred to one or more of the other species of Upper Devonian Dalmanellas according to the revision by Professor Williams since they are *all* confined to the Chemung formation.

Athyris polita is listed by Professor Schuchert as only Chemung,[3] but Mr. Butts has recorded it from the Oswayo formation, which is considered Mississippian in age, of the Olean quadrangle in southwestern New York.[4]

Camarotœchia contracta ranges from the Portage to the Waverly according to Professor Schuchert.[5] This statement is apparently correct since both Hall and Williams reported it from the Ithaca member of the Portage formation at Ithaca, N. Y., while Hall identified as this species specimens from the Waverly of Licking County, Ohio; Butts from the Cattaraugus formation of the Olean quadrangle in southwestern New York[6] which he called "Devono-Carbonic," Professor Glenn Devonian, and Dr. Clarke was disposed to put in the Paleocarbonic [Mississippian];[7] and Kindle has reported it from the Waverly of southwestern Virginia.[8] It is, however, true that this species occurs most abundantly and frequently in the Chemung and it is comparatively

[1]N. Y. State Mus. Bull. 52, 1902, p. 526, and ibid., Bull. 69, 1903, p. 999 for Dr Clarke and pp. 994, 995 of the latter for Mr. Butts.
[2]Bull U. S. Geol. Survey, No. 244, 1905, p. 58.
[3]Ibid., No. 87, p. 149.
[4]N. Y. State Mus. Bull. 69, 1903, p. 995.
[5]Bull. U. S. Geol. Survey, No. 87, p. 165.
[6]N. Y. State Mus., Bull. 69, pp. 993, 994.
[7]Ibid., pp. 968, 997, 999, and legend of stratigraphic map of Olean quadrangle.
[8]Bull. U. S. Geol. Survey, No. 244, p. 31.

rare in these earlier and later formations; so in reality it is a Chemung species.

Productella hirsuta also occurs infrequently in the Chagrin shales of Chippewa Creek, which is listed by Professor Schuchert as only in the Chemung,[1] and is given by Professor Williams as one of the diagnostic Chemung species.[2]

Professor Williams published a list of 12 dominant Chemung species of Chautauqua County, the southwestern one of New York, based upon the work of Prof. G. D. Harris, in which the two most abundant species are *Camarotœchia contracta* and *Spirifer disjunctus*, while another one is *Athyris polita.*[3] In a similar list for the Genesee section *Spirifer disjunctus* and *Camarotœchia contracta* are the most abundant species, while *Productella hirsuta* is another one.[4] In addition it contains *Athyris angelica,* which is closely related to *A. polita,* and *Dalmanella leonensis,* which resembles somewhat the young forms of *D. tioga.*

The fact that of the four most abundant species in Chippewa Creek *Dalmanella tioga* is only known in the Chemung, while *Spirifer disjunctus* and *Athyris polita* are characteristic Chemung species although they do continue up into the Mississippian, which is also true of *Camarotœchia contracta,* although it does occur in the Portage and Waverly, appears to the writer to support the correlation of these beds with the New York Chemung. This opinion is also supported by the additional fact that two of them, *Spirifer disjunctus* and *Camarotœchia contracta,* are the two leading species in Professor Williams' lists of dominant species for western New York. It is believed that this opinion is supported by additional lists of fossils from a similar stratigraphic position eastward to Pennsylvania. This evidence all appears to favor the correlation of at least these upper beds of the Chagrin formation with the Chemung formation of New York and the Devonian system.

This conclusion is in harmony with the early views of Dr. Newberry who correlated the upper portion of his Erie shale with the Chemung of New York and put it in the Devonian system, although in later years he considered the Chemung as forming the basal part of the Lower Carboniferous. Dr. Newberry in 1873 under his description of the Devonian system of Ohio, wrote as follows concerning the age of the Erie (Chagrin) shale:

"As a general rule the Erie shales are remarkably destitute of fossils, and from this cause their exact geological age was for a long time misunderstood, and has been accurately determined only recently and with much study. From their lithological resemblance to the shales of the Portage group in New York, and from their apparent continuity with

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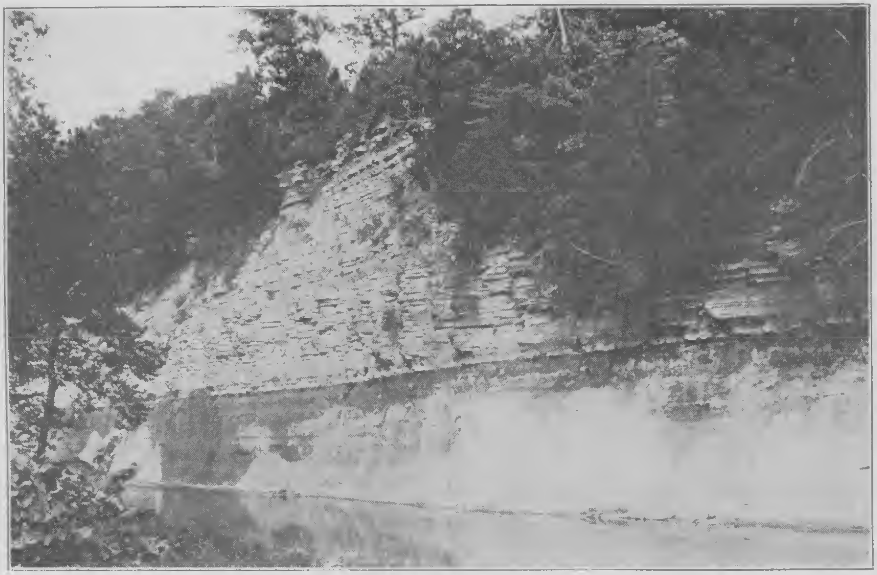
[1]Ibid., No. 87, p. 315.
[2]Ibid., No. 210, 1903, p. 87 for the Genesee section of western New York and No. 244, 1905, p. 57, for the southern extension of the Chemung fauna in the Virginias.
[3]Ibid., No. 210, p. 86.
[4]Ibid., p. 87.



A.—Cliff on Tinkers Creek near Bedford showing contact of Cleveland and Chagrin shales. See page 407.

B—The Berea grit in quarry No. 16 at Peninsula. See page 474.

these, the Erie shales have been generally considered as their equivalent, while the overlying Cuyahoga shale, and other beds which form the northern extension of the Waverly group, have been regarded as the western prolongation of the Chemung rocks of New York. It was our good fortune, however, during our first season of field work, to obtain from several localities in the Erie shales fossils which prove beyond question that the upper portion of these shales are the representatives of the Chemung; and while, from the want of further evidence of the age of the lower beds, we are as yet unable to assert positively that they are continuous with the upper portion of the Portage group, there is scarcely room for doubt that they are the western extension of the Portage sandstones. * * *

"Collections of fossils, which include great numbers of individuals, but not many genera and species, were made by the members of our Corps in the bottoms of the gorges formed by Tinker's Creek and Chippeway [Chippewa] Creek — tributaries of the Cuyahoga in Cuyahoga County—in the valleys of the Chagrin near Euclid, of Big Creek in Lake County, and of Conneaut Creek in Ashtabula County; as well as in the beds of the tributaries of Grand River in the northern part of Trumbull. These fossils include, with some new forms, the following species characteristic of the Chemung in New York: *Spirifer disjunctus*, *S. altus*, *Leiorhynchus mesacostalis*, *Orthis tioga*, etc. The evidence furnished by this group of fossils definitely fixes the geological portion of at least the upper portion of the Erie shale, and dissipates the obscurity that has heretofore hung over the formation."[1]

In the following volume Dr. Newberry stated that "In the sections opened by the valleys of the Cuyahoga and its tributaries, the Cleveland shale is underlain by a few feet of impure limestone and argillaceous shale. The limestone contains *Syringothyris typa*, *Macrodon Hamiltoniæ*, and other Waverly fossils. Beneath these strata are greenish shales, containing *Leiorhynchus mesacostalis*, *Spirifera disjuncta*, etc., Chemung fossils, characteristic of the upper layers of the Erie shale. Here, then, we have the base of the Lower Carboniferous series. The first of the Chemung fossils occur about sixty feet below the base of the Cleveland shale."[2] It appears probable that Dr. Newberry was mistaken in supposing that this impure limestone with the Waverly fauna was subjacent to the Cleveland shale. It is apparently the calcareous deposit at the base of the Bedford containing that fauna. This supposition is corroborated by the much later statement of Dr. Newberry that the occurrence of an earthy limestone beneath the Cleveland shale in the valley of Tinkers Creek, near Bedford, Ohio, was questioned and "efforts made to rediscover the stratum of limestone reported by Mr. Sherwood [at the above mentioned locality] were without success."[3]

[1]Geol. Surv. Ohio, Vol. I, p. 164.
[2]Ibid., Vol. II, pp. 94, 95.
[3]Mon. U. S. Geol. Survey, Vol. XVI, 1889, p. 127.

Prof. C. L. Herrick gave some attention to the Erie shale (Chagrin) and reported the discovery by Dr. Newberry "that the Erie shale is a real equivalent of at least a part of the Chemung or Portage."[1] Professor Herrick also stated that "The following species have been collected by us from the Erie shales: *Spirifer altus, S. disjunctus, S. præmaturus, Leiorhynchus mesacostalis, Streptorhynchus chemungensis, Orthis tioga, Terebratula* sp., *Rhynchonella sappho, Leiopteria* sp., *Orthoceras bebryx, Productus* (like *lachrymosus*)."[2]

Professor Williams has also stated that the Chemung formation of the Genesee Valley section is stratigraphically equivalent, "in part, to the Erie shales of Ohio. But lithologically the Ohio shales are equivalent to the Portage formation of New York."[3] A recent correlation is that of Mr. Butts in the Warren folio of Pennsylvania and New York who states that "Westward, in Ohio, the presence of *Ptychopteria* in the Chagrin ('Erie') shale indicates the equivalence of parts, at least, of the Chagrin ('Erie') and Conewango formations."[4] Mr. Butts puts the Conewango formation in the Devono-Carboniferous and considers the Conewango and overlying Knapp formation as transitional from the Devonian to the Mississippian.

In the article published by Dr. Ulrich while this bulletin was passing through the press he says that:

"The Chagrin formation, or, as Newberry and the geologists of his Survey call it, the Erie shale is not included in the Chattanoogan series. In my opinion it is clearly late Devonian in age and older than the Huron member of the Ohio shale. Furthermore, on the basis of stratigraphic continuity and fossil contents, I can not see how we can avoid correlating the upper part at least of the Chagrin as Chemung, hence, according to the now prevailing interpretation of the New York standard, as latest Devonian."[5]

Dr. Newberry cited the gorge of Chippeway (Chippewa) Creek as one of the localities for fossils in the Erie (Chagrin) shale,[6] and Professor Cushing reported the locality more definitely to the writer.

The bank at this locality, which is on the southern side of the creek, is the best one for the upper Chagrin and Cleveland shales that occurs on the creek. The Chagrin is mostly bluish-gray argillaceous shale with an occasional layer that is slightly harder. The Chagrin part of the cliff, however, 20 feet or so in height, is a smooth shale bank free from talus. Near the base of the cliff and in the bank a little farther down stream some of the thin calcareous and rusty colored layers, with

[1]Am. Geologist, Vol. III, 1889, p. 95.
[2]Loc. cit., f. n. At an earlier date he stated that the above list, with the exception of *Orthis tioga*, had been collected "in the Cuyahoga valley near Peninsula" (Bull. Denison Univ., Vol. IV, 1888, p. 110).
[3]Bull. U. S. Geol. Survey, No. 210, 1903, p. 120.
[4]Ibid., Warren folio (No. 172), Geol. Atlas U. S., 1910, p. 4. col. 3.
[5]Am. Jour. Sci., 4th ser., Vol. XXXIV., August, 1912, p. 171.
[6]Geol. Surv. Ohio, Vol. I, pp. 164–190.

a tendency to concretionary structure, contain a few fossils. They are rare, however, in these layers when compared with the soft shales in the bed of the creek a little farther up stream and on the opposite side where most of the specimens have been collected; but specimens of *Camarotœchia, Dalmanella* and *Spirifer* were obtained.

The contact between the Chagrin and Cleveland shales on this cliff is a very sharp one, a line which can readily be seen at a considerable distance since the Cleveland is the tougher shale and projects slightly beyond the Chagrin. The Cleveland is almost uniformly a black, bituminous tough and rather slaty shale as exposed on the banks of this creek with a thickness of 25 feet as leveled up the steep bank at the lower end of the gorge by Mr. Miller.

At the lower end of the gorge on the southern bank of the creek and about opposite the horizon of fossils in the Chagrin shale on the opposite side of the stream, Mr. Miller leveled the following section:

Section at Lower End of Gorge on Chippewa Creek.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Bedford formation, Euclid lentil.* Fairly thick-bedded, blue, fine-grained sandstone, with an estimated exposed thickness of 12± feet	12±	71
3.	Mainly gray, argillaceous shale; but there are a few layers of thin sandstones, with a fossiliferous layer at the base	14±	59
2.	*Cleveland shale.* A uniformly black and rather slaty shale	25	45
1.	*Chagrin formation,* with a very fossiliferous zone some 20 feet below its top, and in bed of stream	20	20

Farther up the stream on the northern bank, opposite the highest outcrop of the Chagrin shale in the bed of the creek the entire Cleveland shale is again shown and the lower portion of the Bedford formation. Mr. Miller leveled up this bank and obtained 25 feet for the thickness of the Cleveland shale. Next above is 3 feet 7 inches of gray rather gritty shale with some thin layers of sandstone which is the lowest zone of the Bedford formation. This is succeeded by the Euclid sandstone lentil composed of fairly thick-bedded, fine-grained blue sandstone with shale partings. The lower portion is more massive and the upper thinner bedded with more shales. A layer 10 feet above the base as the sandstones are exposed near the creek level farther up the stream, is 1½ feet thick and the thinner layers still farther up the stream show conspicuous ripple-marks. The thickness of this zone on the bank of the creek is estimated as 15 feet although it may, perhaps, be somewhat greater and possibly 20 feet thick. The Euclid sandstone is succeeded by a zone of blue gritty shales containing thin layers of blue sandstone, one-half inch or more in thickness. This zone is 20 ± feet in thickness,

as near as can be determined on account of the difficulty in accurately measuring these two zones. Great blocks of Berea sandstone lie in the bed and on the banks of the stream in the glen and these and other loose material conceal more or less completely the greater part of these two zones. The top of the shale zone is shown on the southern bank just above where the stream is badly choked with great loose blocks of Berea grit. At this locality 3 feet 3 inches of bluish-gray gritty shales to thin sandstones which split into layers one-half inch or less in thickness, are shown, above which is chocolate colored, soft argillaceous shale. On the southern bank of the creek not far below the fall and highway is a marked line of disconformity between the Bedford and Berea formations. At this locality Mr. Miller leveled from the base of the chocolate colored zone up to the base of the Berea sandstone and at the lowest point of the sandstone obtained 16½ feet of shale, at the medium part of the base of the sandstone 27½ feet of shale and at the highest part of the sandstone at least 32 feet of shale and perhaps it is 35 feet thick. This bank shows very clearly the irregular upper surface of the Bedford shale on which the Berea sandstone was deposited. A little farther up the creek is the fall over the lower part of the Berea grit below which is shown the Bedford shale. The top of the Bedford at this locality is generally a bluish-gray soft, argillaceous shale, which at one point on the southern bank is 3 feet 2 inches thick, below which is the soft, argillaceous chocolate shale. A somewhat general section of the Bedford formation compiled from the various outcrops in this glen is given below:

Section of the Bedford and Cleveland Formations on Chippewa Creek.

No.		Thickness. Feet.	Total thickness. Feet.
7.	Irregular base of the *Berea sandstone*	--	--
6.	*Bedford formation.* Bluish-gray, soft, argillaceous shale, as shown on the bank not far below the fall	3±	109
5.	Chocolate colored, soft argillaceous shale, which breaks up into narrow, pencil-like pieces. Thickness varies on the bank from 16½ feet to some 32 feet, due to the eroded upper surface of the shale	32±	106
4.	Blue, gritty shales, with thin layers of blue sandstone, which split into one-half inch and thicker layers	20±	74
3.	Fairly thick-bedded, fine-grained, blue sandstone, with shale partings. The lower layers more massive and the upper part containing more shale. The *Euclid lentil*	15±	54
2.	Grayish shale with a fossiliferous layer at the base. This zone, near the lower end of the gorge, apparently varies in thickness from 3 feet 7 inches on the northern bank, to about 14 feet on the southern. The writer is not positive concerning this difference in thickness; but it was recorded in the two sections, and he has used the greater thickness for this general section	14±	39
1.	*Cleveland shale.* Uniformly black and rather slaty shale	25	25

In the above general section the thickness of the Bedford formation amounts to 81 feet; but if the lesser thickness of the lower zone and the smallest for the chocolate zone be taken then it will be 26 feet less or only 55 feet. A single reading of the barometer from the top of the Bedford, as shown a short distance below the fall, to its base gave 65 feet.

Just beneath the Berea at the bridge, 3 feet or more of the bluish shale at the top of the Bedford is shown while a short distance down the stream the chocolate shale appears below it. The contact between the Bedford and Berea formations is finely shown just below the highway bridge and for a short distance below on each bank. The fall is receding on account of the more rapid disintegration of the subjacent soft Bedford shale followed by the breaking off along the joint lines of the overhanging blocks of Berea grit.

From the highway bridge one-fourth mile east of Brecksville to the old dam above the village the creek has cut a rather narrow gorge in the Berea grit which for most of the distance is bordered by rather low rock cliffs. The lower part of the Berea sandstone is massive as seen at the lower bridge; then comes a zone of considerable thickness which is strongly cross-bedded, some of which is very oblique, while at the top are a few horizontal layers. This structure is similar to that of the Berea as described in several other localities in this general region, as for example Pratt's quarry, northwest of South Park, and on Euclid Creek. There is a cascade over the upper part of the Berea, which occurs a little above the old mill at Brecksville, and in this cascade are a couple of large pot holes.

The top of the formation is reached in the bed of the creek below the old dam a little above Brecksville and, as the dip is down stream, it continues up the creek for some distance above the dam. The upper surface and layer is greatly iron-stained and pitted from the decomposition of iron pyrites or marcasite, which occurs abundantly in nodular or concretionary masses in this upper layer of the formation. This is a lithologic character that is generally observed to indicate the top of the formation. Two readings of the barometer gave in each instance a thickness of 40 feet for the Berea grit on Chippewa Creek, which is probably not far from its actual thickness. Part of the Sunbury shale and the overlying sandstone zone is shown on the southern bank, two or three rods above the last appearance of the Berea grit in the bed of the creek.

On the opposite side of the stream a little above the last mentioned bank may be seen the Aurora sandstone capped by some 25 feet of soft Brecksville shale. The top of the nine-inch sandstone on the southern bank, which is the highest rock it shows, when leveled across the stream corresponds with the top of the sandstone on the northern bank and they are considered as representing the same horizon. The thickness of the sandstone and shale zone on the two banks is approximately the

same and at this locality there is a rather strong southeasterly dip down the creek. The following section has been prepared from the outcrops on these two banks:

Section on Banks of Chippewa Creek above Brecksville.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
9.	*Brecksville shale.* Blackish to bluish-gray, fine, soft, argillaceous shale. Height of bank estimated	25±	--	33	8
8.	Top of *Aurora sandstone and shale zone.* Apparently the same horizon is shown on both the northern and southern banks.	--	9	8	8
7.	Blackish, rather thin, laminated shale, with a thin sandstone near the middle for part of the exposure. This layer varies in thickness from 16 to 17 inches	1	4+	7	11
6.	Thin sandstone, from 4 to 5 inches thick	--	4+	6	7
5.	Arenaceous, gray shale	--	6	6	3
4.	Bluish-gray sandstone, weathering to a buff color, from 6 to 9 inches thick	--	7	5	9
3.	Coarse, arenaceous shale, with calcareous, rusty layer of concretions near the base	--	6	5	2
2.	Bluish-gray, fine-grained sandstone	--	11	4	8
1.	*Sunbury shale.* Black or blackish, rather soft shale, alternating with bluish-gray, soft, argillaceous shale. This shale as weathered on the wet bank does not show the tough, slaty, typical Sunbury shale of central Ohio; but it probably represents that terrane. The lower part of the zone is not exposed, and there is probably about 2 feet more, down to the top of the Berea grit	3	9	3	9

In the above section the zone of bluish-gray fine-grained sandstone alternating with shale, Nos. 2 to 8 inclusive, varying from 4 feet 10 inches to about 5 feet 10 inches, is the one which in northern Ohio generally overlies the Sunbury shale. This zone of sandstone and shale on the upper and northern bank is about 5 feet 10 inches thick and is shown in Plate LII, where Mr. Miller is standing at its base and marking the top with the hammer, while above is some 25 feet of Brecksville shale. Near the lower end of this bank at low water there is shown beneath the sandstone zone about 7½ inches of Sunbury shale and some rods farther up stream, 1 foot 2 inches.

The present state of our knowledge concerning the sandstones of northern and central Ohio does not permit the correlation of this zone with any other sandstone. It is not improbable that it is a local sandstone zone which does not extend to the central part of the state. This opinion is supported in a way by the fact that it does not occur in all

PLATE LII.

Chippewa Creek above Brecksville showing Aurora sandstone and superjacent Brecksville shale.

the sections in the Cleveland region and that in part of the territory east of the Chagrin River a sandstone zone occurs at a higher stratigraphic position where this one is wanting. It is interesting, perhaps, to note that in central Ohio directly overlying the Sunbury shale is a zone of soft gray argillaceous shale from 5 to 10 feet thick, which is succeeded by a sandstone member of the Cuyahoga formation. There is a possibility that the shale zone disappears and this sandstone is the thinned northern representative of the one in central Ohio. Again, the shale may thicken to the north and correspond to the Brecksville and the sandstone member to the Sharpsville, except that those sandstones appear to thin out as followed to the southwest of Cleveland. It is more probable that the sandstone zone between the Sunbury and Brecksville shales of the Cleveland region is a local one; but on account of its stratigraphic importance a geographic name will be of convenience in referring to it. There are other localities where it is fully as prominent as on Chippewa Creek, as for example above Chagrin Falls on that river; but that name like Chippewa has already been used for a geological formation. This member of the Orangeville formation is well shown on the Aurora Branch of the Chagrin River, as will be seen from the description of that section in the next chapter, and it has been named the Aurora sandstone from that locality.

On this part of Chippewa Creek the rocks are rising as it is followed up stream; consequently although the Aurora member is comparatively thin it may be followed for some distance up the stream. The top, however, passes beneath the creek level a few rods below the iron bridge one-half mile northwest of Brecksville.

Just above this bridge on the southern side of the creek is a bank of soft, finely laminated blackish to bluish-gray shale, probably 25 feet high. This is the soft shale of the Orangeville formation and at the second bank on the same side of the creek, 75 feet or more of shale with similar lithologic appearance is shown. This bank begins near where a southern branch enters the creek, and the shale is finely shown on the eastern side of this branch, and as seen from the valley, it looks like a bank of uniformly soft dark colored shale. The topographic map indicates that the cliff at this junction of the two streams is 120 feet or more in height. The high ground above this cliff probably contains thin sandstones of the succeeding terrane, although no indication of it was visible from the valley. The writer would say that the cliff is apparently composed of the soft blackish to bluish-black shale with no sandy layers of any prominence. A similar bank of the fine shale, although not so high, occurs on the northeastern side of Chippewa Creek at this locality just above the forks of the highway. These banks are typical illustrations of the soft shale of the Orangeville formation, and this is an excellent locality for gaining an idea of its general appearance. It forms the lower part of Newberry's

Cuyahoga formation in the Cuyahoga basin; although he apparently did not fully appreciate the lithologic character of this part of the formation since his description, apparently for the entire formation in Cuyahoga County, gave it as composed "mainly of gray argillaceous shale with thin flags of fine sandstone scattered through it."[1] In Summit County in which Newberry stated that the formation is better exhibited than in any other part of the State he reported that "the Cuyahoga shale exhibits little variety in composition, and consists of a mass of soft argillaceous material interstratified with thin and local sheets of fine grained sandstone, rarely thick enough to serve as flagging."[2] This description was apparently derived mainly from the exposures which succeed the Orangeville formation, and to which it applies much better than to the lower 125 feet or more of the Cuyahoga. Dr. Newberry speaks especially of his studying the upper portion of the terrane in the river valley below Cuyahoga Falls, and it is thought that his opinion regarding its lithologic composition was derived pretty largely from its upper portion as shown in that region.

The soft shale of the Orangeville formation continues up Chippewa Creek for 1¼ miles or farther, above the highway forks mentioned above. Lithologically the shale remains like the lower part until well toward the top. Within 30 feet of the top the shales are soft and black to bluish-black in color; but the upper 12 feet consists of fine, rather sandy bluish shale in which are two thin layers of sandstone. At this bank, where it is considered that the top of the Orangeville formation occurs, is a small reverse fault, similar to those which were noticed in the lower shales in Cleveland. A single reading of the barometer gave 105 feet from the top of the Aurora sandstone to the top of the Orangeville formation. If to this the combined thickness of the Aurora sandstone and Sunbury shale be added, which we will call approximately 10 feet for this creek, it will give 115 feet for the thickness of the Orangeville formation on Chippewa Creek.

The line marking the top of the Orangeville formation is drawn at the base of the first sandstone of any considerable thickness, which is the lower limit also of a marked sandstone zone. This contact is clearly shown at two places not far apart on the southern bank of the creek. The lower one gives the following section:

Section on Southern Bank of Chippewa Creek Showing Top of Orangeville Formation.

No.		Thickness. Feet.	Total thickness. Feet.
4.	Coarser shale to sandstone, estimated as 8 feet	8±	30
3.	Rather fine shale, thickness estimated as about 5 feet	5±	22

[1]Geol. Surv. Ohio, Vol. I, p. 185.
[2]Ibid., p. 210.

No.		Thickness. Feet.	Total thickness. Feet.
2.	Sandstone zone, compact, blue, rather massive stone, estimated thickness about 5 feet	5±	17
1.	Top of *Orangeville formation*. Fine bluish, rather arenaceous shale, with only two thin sandstone layers in a thickness of about 12 feet. The next lower exposures on the creek are composed entirely of fine, rather soft, bluish-black to black shales	12±	12

The second locality, which is a little farther up the creek, where the sandstones make a small fall, does not show so high a bank as the lower one but is readily accessible for measurement.

Second Section Giving Top of Orangeville Formation.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
6.	Compact, blue, fine-grained sandstone	--	11	8	--
5.	Arenaceous shale	--	$1\frac{1}{2}$+	7	$\frac{1}{2}$
4.	Blue, compact, fine-grained sandstone	1	6	6	11
3.	Top of *Orangeville formation*. Blue shale in fine laminæ, partly argillaceous, and then somewhat sandy near the base	4	3	5	5
2.	Thin, bluish sandstone layer, varying from 1 to $3\frac{1}{2}$ inches in thickness	--	2±	1	2
1.	Blue, rather arenaceous, but fine shale to bed of creek	1+	--	1	--

Beginning with the base of the blue compact fine-grained sandstone, No. 4 in the second section and No. 2 in the first one, there is a rather definite and heavy sandstone zone about 5 feet in thickness, while the succeeding rocks are rather thin-bedded sandstones alternating with bluish argillaceous or arenaceous shales. There is certainly a marked lithologic change at the horizon indicated, and therefore it has been selected for the line of division between the Orangeville formation and the succeeding one, although the base of the lowest thin sandstone in No. 1 of the first section may perhaps represent the thin sandstone, which was called the base of the Royalton formation in the Rocky River sections to the southwest of Cleveland. Unquestionably these upper rocks correspond with Dr. Newberry's lithologic description of the Cuyahoga shale and apparently the lower portion may be regarded as the somewhat modified western extension of the Sharpsville sandstone, which in western Pennsylvania and eastern Ohio immediately succeeds the Orangeville formation.

Ten feet above the top of the Orangeville formation, according to two readings of the barometer, is a conspicuous sandstone stratum, about $3\frac{1}{2}$ inches in thickness, which forms the floor of the creek for several rods due to a sharp rise in the rocks as followed up stream.

This stratum, which probably occurs near the base of No. 4 of the first section, is very compact and forms a slight fall at its lower end. It contains immense numbers of the form generally called *Spirophyton* or *Taonurus* which appear to the writer to have probably been made by marine worms.

Farther up the stream and not far below the north and south road which crosses the creek in the western part of Brecksville Township, is an exposure of about 20 feet on the southern bank. The lower few feet are composed of bluish arenaceous or argillaceous shales with an occasional very thin sandstone layer and somewhat calcareous and rusty concretionary layers, similar in appearance to those in the Chagrin. Then a layer of fine-grained, bluish sandstone about a foot in thickness with a shale parting near the middle occurs, which by the barometer is 30 feet above the top of the Orangeville formation. The bank shows 15 feet of bluish shales with frequent thin, alternating layers of sandstone from 4 to 6 inches in thickness succeeding the 1-foot stratum of sandstone. About 45 feet of rock succeeding the Orangeville formation is shown to the top of this cliff, which is the highest outcrop of the older rocks seen on the stream. There are rather steep banks on the creek for a mile or more above, which were examined at numerous places but only glacial deposits or soil were found. In this 45 feet of rock succeeding the Orangeville formation, the thickest and most massive sandstones occur at its base within the first 5 feet. As a rule in the succeeding 40 feet the sandstones are thin-bedded and alternate with bluish clay or sandy shales, which probably form the greater proportion of the total thickness. It is probable that this entire 45 feet of rock was deposited during the same time that the Sharpsville sandstone was being deposited in what is now eastern Ohio and western Pennsylvania. The deposits, however, on Chippewa Creek contain a much larger proportion of shale and lithologically do not closely resemble the typical deposits of the Sharpsville sandstone. In a somewhat general and provisional way, however, it is perhaps not incorrect to apply the name Sharpsville to these deposits.

The Orangeville formation is probably shown to better advantage on Chippewa Creek than at any other locality in the vicinity of Cleveland. It may readily be divided into three members of which the lower and upper ones are shales, separated by a sandstone. The lower member is the Sunbury shale, which is succeeded by a zone of sandstone or sandstone alternating with arenaceous shale that forms the second member to which the name of Aurora sandstone has been given from its outcrops on the stream of that name. The combined thickness of these two members, however, on Chippewa Creek is scarcely more than 10 feet, above which is 105 feet or more of soft dark colored shale. This shale corresponds more nearly with the original Orangeville shale of Dr. White than any other portion of the

formation as shown on Chippewa Creek. Still, according to Dr. White's later definition of the shale, it undoubtedly has the limits which have already been explained in this bulletin. On account of the sandstone member, it is considered that formation is a better term than shale to use for the entire terrane. It will be convenient, however, to have a distinctive name for the upper and thickest member of the formation, and since Orangeville is used for the complete terrane, in order not to use that name in two senses, a new one is needed for the upper shale member. There are no better exposures of this member to be found than on the cliffs of Chippewa Creek, beginning above the highway bridge one-half mile northwest of Brecksville and continuing, with some interruptions, for one-fourth mile or farther up this creek and its first southern branch. The highest and most conspicuous shale banks are from one-half to one mile west to northwest of Brecksville village, not far from the center of Brecksville Township, and for this reason the name of *Brecksville shale* is given to the upper member of the Orangeville formation.

The thickness of the rocks and the several formations shown from the mouth of Chippewa Creek to its highest outcrops is represented diagrammatically in the following section. The thickness, however, was determined largely by barometer, and on this account and some others is not so accurate as in some of the other sections.

General Section of Formations on Chippewa Creek.

370′		Highest outcrop on creek	
	45′	Sharpsville sandstone	
325′			
	105′	Brecksville shale	Orangeville formation 115 feet
220′			
	5′	Aurora sandstone	
215′			
	5± ′	Sunbury shale	
210′			
	40′	Berea grit	
170′			
	80′±	Bedford formation	
90′			
	25′	Cleveland shale	
65′			
	20′		Chagrin shale
45′		Fossil zone	
	45′		
0′		Level of Cuyahoga River	

The above estimate of 370 feet for the thickness of the rocks from the level of the Cuyahoga River at Brecksville station to the highest outcrop of the Carboniferous rocks on Chippewa Creek is probably not very seriously in error since this outcrop, which was located rather

accurately on the topographic map, is approximately 380 feet higher than the river level.

Some search was made on the upper tributaries of Chippewa Creek in the hope of carrying the section higher than at the locality already reported; but without any distinct success. Thin-bedded bluish sandstones were noted in places on the road south of the creek, about $1\frac{1}{4}$ miles above the road forks and near the first run, which are perhaps 90 feet higher than the outcrop on the creek bank and are below the Sharon conglomerate. The formation just mentioned is the conglomerate often found at the base of the coal-measures, and was named by Dr. I. C.White in 1879 (?) from outcrops on the hill west of Sharon, Pennsylvania, about on the Ohio-Pennsylvania State line.[1]

A similar search was made along the upper course of Rocky River and its branches in the southeastern part of Royalton and northeastern part of Hinckley townships, but with the exception of the Sharon conglomerate, only glacial and alluvial deposits were seen. The higher ground of this region is capped by the Sharon conglomerate, outcrops of which were noted at several places. One of these is on a small run west of Rocky River and the James Steigler house, about where the east and west crossroad near the southern line of Royalton Township turns to the southeast. At this place 45 feet of rock is shown which is mainly a coarse grit in massive layers with some pebbles. There is an occasional zone with numerous large white quartz pebbles; but these are infrequent. It has been quarried at this locality to a slight extent. Rocky River at the crossing on the township line, shows nothing but boulder clay and other glacial and alluvial deposits. The small but steep hill, however, just to the east is capped by the massive ledges of the Sharon conglomerate which is largely a coarse grit containing some pebbles. At the Rocky River bridge of the northern east and west road in Hinckley Township the stream is sluggish, the valley broad with alluvial deposits and drift on the hill slopes. On the steep hill to the west ledges of massive Sharon conglomerate appear at an elevation of 110 feet (barometric) above the river and then continue for 70 feet nearly to the top of the hill. The topographic map indicates that the highway , where it crosses the top of the hill, is some 200 feet higher than the river to the east, so that probably somewhat more than 70 feet of the conglomerate remains on this hill.

Section Near North Royalton. — Rocky River is not a tributary of the Cuyahoga River but on the contrary enters Lake Erie west of Cleveland. The section of its tributary, however, near North Royalton is given in this chapter of the present bulletin, because it furnishes a continuation of the Chippewa Creek section, and hence is of special interest in this connection, since it gives information concerning the

[1]Second Geol. Surv. Pa. Q^2, p. 296.

upper deposits of the Cuyahoga terrane. North Royalton is located near the center of Royalton Township on the high ground which lies in the great loop of the Rocky River. There is a steep slope on the western side down to the valley of Rocky River which lies 375 feet or more below the village. There are numerous runs from the high land to the river, which have cut small gorges of greater or lesser depth in this slope. The majority of them, however, show only glacial or alluvial deposits. One, however, on the farm of Jacob Driesbach, shows about 150 feet of the older rocks which is a very interesting place for study. The first rocks in the upper part of the glen begin one-half mile northwest of the center of North Royalton and then continue down the steep slope of the hill until the more gradual slope is reached when boulder clay, drift and alluvial deposits are found. Unfortunately rather limited time was available for the study of the gully; but the following section was determined:

Section of Gully Northwest of North Royalton.

No		Thickness. Feet.	Total thickness. Feet.
12.	*Upper limestone*. The highest outcrop seen is a blue, fossiliferous limestone in places fully 1 foot thick. In a branch gully, 2 or 3 feet lower, apparently a similar layer is shown	1±	150½
11.	Mostly covered interval; but at the base are thin layers of bluish sandstone	24	149½
10.	Calcareous layers, 1 to 2 inches thick, which are fossiliferous. Above and below the calcareous zone are thin layers of bluish sandstone	¾±	125½
9.	In the upper part are thin, blue sandstones, with an occasional thin, calcareous layer, in which fossils are abundant. This is especially true of one about 9 feet below the base of the calcareous zone, in which are numerous fossils, especially a large *Productus*. The sandstones are bluish to gray in color, rather coarse-grained, and split into thin, somewhat laminated layers. Fossils occur in the sandstones, but not so abundantly as in the calcareous layers. There are occasional concretions, and likewise, layers with ripple-marks	24	124¾
8.	*Lower limestone*. Impure, blue, compact limestone, about 9 inches thick, which grades below into thin-bedded, bluish sandstone. It is similar to the layer at the top of the section, but apparently not so much of a limestone, and is 50 feet lower by the barometer	¾±	100¾
7.	Mainly thin, blue sandstones, alternating with blue shales..	50	100
6.	Fairly soft, rather argillaceous shales in bed of run. Lower are thin, bluish, laminated sandstones, alternating with these soft shales. Some of the sandstones show ripple-marks	15	50

No.		Thickness. Feet.	Total thickness. Feet.
5.	A blue, calcareous layer, somewhat similar to the higher ones, but mainly crinoidal, about 2 inches in thickness. Several of these layers occur in the following 5 feet, some of which are rather concretionary, like those noted in lower shales	5	35
4.	Bluish, rather soft, argillaceous shale	5	30
3.	Sandstones, alternating with shales. Although some of these shales are argillaceous, all of them are much coarser than those of the Brecksville	20	25
2.	Sandstone zone of bluish to grayish color, the lower layer $1\frac{1}{2}$ feet thick	$1\frac{1}{2}$	5
1.	Thin, grayish or bluish sandstones and shales to the lowest exposures. A somewhat calcareous and thin layer about 3 feet below the base of the thick sandstone contains some fossils, and specimens of *Productus* and *Spirifer* were collected. Fossils, however, in the lower 100 feet of the section are much less frequent than between the two limestones, Nos. 8 and 12. Below this horizon only boulder clay and other glacial and alluvial deposits were seen	$3\frac{1}{2}$	$3\frac{1}{2}$

The lowest outcrops in this gully are according to the barometer from 135 to 145 feet higher than the level of Rocky River opposite the cliff of Brecksville shale on the Edward Meacher farm, and they are above the top of the Orangeville formation. A reading from the mouth of the run entering East Branch from the east about a mile above Roy's Mill made the interval from that point up to the lowest outcrops in this gully 190 feet.

Another gully to the southwest of North Royalton also shows Carboniferous rocks along part of its course, and according to the barometer, they are shown about 20 feet lower than on the former run. This gully is crossed by the diagonal road running southwest from North Royalton about one-half mile southwest of the village. The lowest rocks are shown only a few rods below the bridge, and consist of bluish argillaceous or somewhat arenaceous shale with thin layers of blue sandstone. Some layers are slightly calcareous, with a rusty color, similar in appearance to those in the Chagrin formation. There are traces of fossils in the soft shales. There is too much sandstone in this outcrop for the typical Brecksville shale; and it is 125 feet (barometric measurement) above Rocky River opposite the Meacher cliff of Brecksville shale.

There are fair exposures from the base for about 95 feet (barometric measurement) up this run. Bluish shales with thin sandstones somewhat laminated and an occasional thin slightly calcareous layer are the prevailing rocks. About 65 feet above the base is a somewhat calcareous, bluish stratum about 7 inches thick which resembles an

impure limestone. The highest layer seen is a thin one of laminated bluish sandstone in the bed of the run. Outcrops of these bluish, thin-bedded sandstones were seen at a few other places in the runs or on the highways descending this steep western slope; but none of them were extensive enough to be of any particular interest.

The Brecksville shale is shown on the western bank of Rocky River on the farm of Wm. Meacher, perhaps about one-half mile below the river bridge on the road to the southwest of North Royalton. It may also be seen from the eastern side of the river not far from the house of Mr. Edward Meacher. The bank is about 18 feet high, and is composed of black to bluish-black soft shale. Apparently no sandy layers occur in it, and it is typical Brecksville shale. According to Mr. Edward Meacher another bank of similar shale occurs about one-half mile below the one examined; while a third bank was reported below the second highway bridge over the river in Strongsville Township.

Brandywine Creek Sections. — Brandywine is the next large creek south of Tinkers which enters the Cuyahoga River from the east. That part of its course which has rocky banks lies in the southern part of Northfield Township, which is in the northern tier of townships in this county. Brandywine Falls over the Berea grit on this creek are about 7½ miles south of the glen on Tinkers Creek near Bedford. The creek has cut a gorge of some depth in the Bedford and Chagrin shales below Brandywine Falls and the rocks of this portion of its course will now be described:

Section of Gorge and Brandywine Falls.

No.		Thickness. Feet.	Total thickness. Feet.
10.	*Sunbury shale.* By the side of the road, just south of the falls, is an outcrop of thin, black shale. As weathered, it is frequently much iron-stained on the outside and rather brownish inside. Fragments of fish scales and spines, specimens of *Lingula melie* Hall and *Orbiculoidea herzeri* Hall and Clarke, and fragments of plant stems like *Cordaites* were found, especially in shale thrown out of a trench for a pipe line in December, 1906	6	174
9.	Covered interval; but on the northern bank at the pathway, are apparently some sandy shales, with the lithologic appearance of the Berea, probably belonging in part of this interval. The writer is not sure, however, that these sandy shales are in place; but in the southern quarry at Peninsula, and in a creek to the south of the quarry, similar sandy shales form the upper part of the Berea formation, which apparently supports the above opinion. If this interval does not belong in the Berea, then the massive sandstone at the top of the bank above the fall marks the top of the formation	5	168

No.		Thickness. Feet.	Total thickness. Feet.
8.	*Berea grit.* Massive, coarse-grained sandstone, forming crest of falls. The top of this zone is shown on the northern bank at the falls, and apparently in a small tributary entering the creek from the south, above the highway	$17\frac{5}{6}$	163 —
7.	Shaly zone, with some fairly thick layers, which are, however, irregular so far as thickness is concerned	$9\frac{3}{4}$	145
6.	Fairly massive sandstone, some of the layers showing conspicuous ripple-marks. The grit forms ledges on both sides of the creek for some distance below the falls. The sum of the thickness of these three sandstone zones is $34\frac{1}{3}$ feet, all of which clearly belongs in the Berea formation, and if to this the superjacent shaly and covered interval of 5 feet be added, it will give $39\frac{1}{3}$ feet for the thickness of the formation	$6\frac{3}{4}$	$135\frac{1}{4}$
5.	*Bedford formation.* It forms the lower part of the fall, where $29\frac{1}{2}$ feet is shown, which is mainly a fairly bluish, argillaceous shale, with occasional thin layers of sandstone, perhaps an inch or so in thickness, and some of which are slightly calcareous. Not infrequently, lenticular concretions occur, which are similar to those in the upper part of the Cuyahoga terrane. Some time was devoted to hunting for fossils in this shale; but only a comparatively small number of specimens was found. The most abundant one is *Chonetes*, which is common in the lower few inches of shale. Specimens of *Productus*, *Camarotœchia*, *Athyris* and *Palæoneilo* (?) also occur. It was leveled from the top of the Cleveland shale to the base of the Berea sandstone in the fall, and also on the northern bank of the creek some rods below the fall, where the entire thickness of the formation is shown, and in each instance 48 feet was obtained. At this latter locality, the lower part of the formation is shown, which also consists of bluish shales and thin sandstones. Although only 6 miles south-southeast of Sagamore Creek, there is no representation here of either the Sagamore or the Euclid sandstone lentils; while instead of a thickness of some 90 feet as in the Sagamore Creek region there is only 48 feet. From the top of the Cleveland shale to the top of the massive Berea is $82\frac{1}{3}$ feet by level, and 85 feet by barometer	48	$128\frac{1}{2}$
4.	*Cleveland shale.* This is shown in bed of creek not far below the fall and on both banks farther down stream. The upper part is even bedded, somewhat slaty, but splitting up into laminæ on weathering. The lower part is rather more massive, especially as seen in gullies on creek bank where it has been uncovered for only a comparatively short time, apparently a little gritty and also contains bits of mica. In a gully which will be described later, in connection with the top of the		

No.		Thickness. Feet.	Total thickness. Feet.
	Chagrin formation, $15\frac{1}{2}$ feet is shown. The entire formation is shown in the bed of the creek, the top of which is only a few rods below the foot of the fall, where its thickness as determined by Mr. Morse, is $13\frac{1}{2}$ feet	$15\frac{1}{2}$	$80\frac{1}{2}$
3.	*Chagrin formation.* The top of this formation in the creek, and on the bank for some little distance below is marked by a fine-grained, gray sandstone, which in places is 14 inches in thickness, and makes a small fall. On the southern bank, a few rods below the fall, the contact with the Cleveland shale is shown. Some 10 feet of coarse, gritty Cleveland shale occurs in the cliff above the sandstone, and the lithologic change is sharp at this contact of the two formations. Below the top sandstone of the Chagrin formation are other layers of rather coarse sandstone, which make small falls or rapids. Alternating with these sandstones are softer layers of olive shales, which frequently contain fossils in considerable abundance. The most abundant species are *Spirifer disjunctus* Sowb., *Athyris polita* Hall, and Productellas. This is an excellent locality in which to collect the fauna of the upper Chagrin formation. Some of the coarser layers in the lower part of the glen show ripple-marks	20	65
2.	Covered interval; from about the base of the lower cliff at the end of the gorge down the stream, in which are frequent banks of boulder clay	40±	45
1.	Blue Chagrin shale; about 5 feet of which is shown, and this is as far as the stream was followed	5	5

On the southwestern bank of the stream not far above the lower end of the gorge the water from the road gutter, which passes under the highway through a sewer pipe, had in October, 1906, recently cut through the surficial deposits of this steep slope to the bed rock. At this locality the following section was shown in October, 1906:

Section of Bank of Brandywine Creek Below the Fall.

No.		Thickness. Feet.	Total thickness. Feet.
5.	Soil and boulder clay to mouth of sewer pipe below highway	35	$85\frac{1}{2}$
4.	*Bedford shale.* Gray, soft shale, with an occasional thin sandstone. Sharp contact with subjacent Cleveland shale shown under roots of a stump which extended across the gully	15	$50\frac{1}{2}$
3.	*Cleveland shale.* Black and bituminous, lower part massive, somewhat gritty with specks of mica	$15\frac{1}{2}$	$35\frac{1}{2}$
2.	Covered interval of about 6 feet, most of which probably belongs in the Chagrin formation	6±	20

No.		Thickness. Feet.	Total thickness. Feet.
1.	*Chagrin formation.* Olive, soft shales at the top of which the barometer read the same as at the top of the formation farther up the creek, then there is a covered interval, below which on the creek bank are bluish to olive, argillaceous and arenaceous shales, alternating with thin sandstones. The shales contain numerous specimens of *Spirifer disjunctus* Sowb., together with an occasional specimen of some other species	14	14

A few rods farther up the creek, on the same bank, the stream from the highway gutter passing through the next higher sewer pipe has cut another gully which shows the following section:

No.		Thickness. Feet.	Total thickness. Feet.
4.	Soil and boulder clay to mouth of sewer pipe, not measured	--	--
3.	*Bedford formation.* Bluish to gray shales, alternating with thin sandstones, after about 5 feet of soft, basal shales	18±	53
2.	*Cleveland shale.* Sharp contact with Bedford formation, and lithologic change at once. Black shale, which in upper part of exposure splits into rather thin laminæ; but lower part is massive and somewhat gritty	10	35
1.	Covered to creek bank where Chagrin shale is shown near water level	25	25

At the end of the gorge is a rather high cliff, perhaps 50 feet high the lower part composed mainly of bluish Chagrin shale with some sandstone layers capped by a more prominent sandstone. Above this sandstone is the Cleveland shale, which on the weathered surface has a rusty appearance.

In the above section there is $15\frac{1}{2}$ feet of Cleveland shale, 48 feet for the Bedford formation and $34\frac{1}{3}$ feet of the Berea grit, to which may perhaps be added 5 feet of thin-bedded layers above the top of the massive rock overlooking the fall, making a total of $39\frac{1}{3}$ feet. It will be remembered that the section above the Cleveland & Pittsburgh Railroad viaduct near Bedford, which is about $7\frac{1}{2}$ miles north of Brandywine Falls, gave $39\frac{1}{3}$ feet for the thickness of the Berea grit; while on Chippewa Creek, $5\frac{1}{2}$ miles northwest of Brandywine Falls, 40 feet was obtained. At the latter locality the Bedford formation is apparently 65 feet thick, while in this section it is only 48 feet.

The shales and thin sandstones of the upper part of the Chagrin as exposed in the lower part of the gorge below Brandywine Falls are fairly fossiliferous. Slabs of these sandstones washed out by the stream and picked up loose from along its bed below the top of the Chagrin formation furnished the following species:

1. Spirifer disjunctus Sowb.
   These specimens have about 12 plications in the sinus and it is stated in Hall's description of this species that "The mesial fold and sinus are each marked by about ten, sometimes twelve or fourteen ribs near the front." There are specimens from this locality with the cardinal extremities as long as in fig. 19, pl. 42, Vol. IV, Pal. N. Y., and others like fig. 13.

   Specimens were compared with authentic ones of this species in both the Cornell and New York State museums, so that there is no question concerning the accuracy of the identification.
2. Athyris polita Hall
3. Productella lachrymosa Con. var. stigmata Hall
   The pustules of this specimen are of about the same strength and closely resemble those of the original of fig. 36, pl. 25, Vol. IV, Pal. N. Y., of this species and variety. The Ohio specimen is smaller than most of those of this variety in the collections of the New York State Museum.
4. Chonetes setiger Hall
   Specimens marked with 40 lines (striæ) near outer margin of shell, and compared with authentic specimens of this species at Cornell University, with which they agree closely.
5. Ambocœlia umbonata Con. var. gregaria Hall
   A specimen of a dorsal valve from Brandywine Creek has the rather narrow and fairly deep median sinus, which is characteristic of this variety, since it is stated that the dorsal valve of *A. umbonata* has "no perceptible mesial fold, furrow or impressed line."

   The original of fig. 23, pl. 44, Vol. IV, Pal. N. Y., which is from the Chemung of Randolph, Cattaraugus Co., N. Y., was studied in the State Museum. It is the interior of a dorsal valve and associated with it is a considerable number of other impressions of this variety. Specimens from this locality agree with others on the block from the Chemung formation of Jasper, Steuben Co., N. Y., which contains the original of fig. 5d, p. 267, Geol. Rept. 4th Dist., N. Y., that later became one of Hall's types of this variety, and which is now in the American Museum. There are specimens of ventral valves on this New York block which agree precisely with the Ohio ones, and the writer considers them identical. Professor Schuchert recognizes this variety as a distinct species, which is given as restricted to the Chemung.[1]
6. Camarotœchia cf. contracta Hall
7. Leptodesma sp.
   Imperfectly preserved specimens.

From shales in the upper part of the Chagrin formation collected along Brandywine Creek, the following species were obtained:

[1]Bull. U. S. Geol. Survey, No. 87, p. 140.

1. Spirifer disjunctus Sowb. -- (c)
   The specimens from the shales do not show mucronate extensions of the cardinal extremities; but in general are of the narrow type similar to those of Chippewa Creek.
2. Athyris polita Hall -- (c)
3. Ambocœlia umbonata Con. var. gregaria Hall ---------------- (c)
4. Chonetes setiger Hall-- (c)
   Surface marked by 40, or perhaps more rounded lines (striæ), and specimens were compared with authentic ones of this species at Cornell and the American Museum. At the latter museum they were compared with the original of fig. 4, pl. 22, Vol. IV, Pal. N. Y., from the Chemung of Painted Post, N. Y., and there is apparently no question concerning the identity of these specimens with this species. It is listed, however, by Schuchert as ranging from the Marcellus to the Waverly[1] and it is reported by Hall and Clarke from Penfield, in the southern part of Lorain Co., Ohio, which is in the Waverly.[2]
5. Productella lachrymosa Con. ---------------------------------- (c)
   This is another species that Schuchert lists as only in the Chemung.[3]
6. Productella arctirostrata Hall -------------------------------- (rr)
   The largest Ohio specimen closely resembles one from Mansfield, Pa., at Cornell University, which was identified by Dr. Kindle as this species. This identification is also supported by comparison with specimens from near Mansfield, Tioga Co., Pa., now in the American Museum, which were identified as this species by Professor Hall. According to Schuchert, the species is restricted to the Chemung formation.
7. Productella striatula Hall (?)--------------------------------- (rr)
   One specimen, with spines and concentric folds, resembling this species.
8. Productella hirsuta Hall var. rectispina Hall ------------------ (r)
   The Brandywine Creek specimens were compared with the originals of figs. 31–35, pl. 24, Vol. IV, Pal. N. Y., which are in the American Museum, and they agree very well in the size and character of the small spines. The spines are perhaps a little coarser on most of the New York specimens; but the original of fig. 32 agrees closely with some of those from Ohio. The figures are not especially accurate representations of the types. The New York specimens are rather wider in proportion to their length than the Ohio ones; but one from Meadville, Pa., so identified by Hall, is almost a counterpart in size and shape of some of the Ohio ones. Hall, in his original description, mentioned the strongly wrinkled surface near the cardinal lines of the Meadville specimens. This variety is recorded by Schuchert as only in the Chemung.
9. Strophalosia hystricula Hall --------------------------------- (rr)
   The larger one of the two specimens agrees rather closely in

[1]Ibid., p. 178.
[2]Pal. N. Y., Vol. VIII, pt. I, pl. 16, fig. 2.
[3]Loc. cit., p. 315.

outline and strength of spines with the original of fig. 4, pl. 26, Vol. IV, Pal. N. Y., of this species, which is from the Chemung of Forrestville, Chautauqua Co., N. Y. There are also other specimens in the American Museum, from the Chemung, near Dexterville, N. Y., which are similar to the Ohio specimens. This species, according to Schuchert, is restricted to the Chemung.

10. Reticularia præmatura (Hall) Schuchert ---------------------- (r)

The Ohio specimens were compared with types of this species, from Meadville, Pa., which are in the New York State Museum, and they are identical. Smaller specimens from Brandywine Creek are similar to the original of fig. 31, pl. 33, Vol. IV, Pal. N. Y., from Meadville, Pa., which is associated with several specimens of *Spirifer disjunctus* Sowb., on the same block. Professor Hall gave this species as in the Chemung, at Meadville, Pa., and among specimens from Oil Creek, associated with *Spirifer disjunctus*. Professor Herrick figured it under the generic name of *Martinia*, from the Erie shale, supposedly of Ohio (Geol. Surv. Ohio, Vol. VII, pl. 23, fig. 12), and the species was also reported by him at an earlier date from these shales, under the generic name of *Spirifer* (Am. Geologist, Vol. III, 1889, p. 95, f.n.). A figure of a specimen of this species, from the Chemung formation of Allegany Co., N. Y., is given by Hall and Clarke, in Pal. N. Y., Vol. VIII, pt. II, 1894, pl. 36, fig. 23.

11. Camarotœchia cf. contracta Hall ------------------------------ (c)

One broken specimen has radiating lines on the plications, and has somewhat the general appearance of a Liorhynchoid shell. Professor Whitfield called it *C. contracta*, and said that specimens preserved in shale show fine radiating lines. The specimens of this species, however, in the American Museum, do not show these fine radiating lines.

12. Lingula sp. -- (rr)

13. Schizodus cf. chemungensis (Con.) Hall ----------------------- (rr)

The Ohio specimens are more circular in outline, and the umbonal slope is not so conspicuous as on specimens from Meadville, Pa., identified by Dr. Kindle as this species, which were examined at Cornell University.

14. Phthonia sp. -- (rr)

Posterior part of shell, which has interrupted radiating lines (striæ) like those of *P. sectifrons* (Con.) Hall.

15. Sphenotus contractus Hall ------------------------------------ (rr)

The Ohio specimens agree more closely with the figures of this species than specimens from the Chemung at Cuba, N. Y., which were so identified and published by Professor Williams (Bull. U. S. Geol. Survey No. 41, p. 64). The range of this species is given by Grabau and Shimer as only Chemung of New York and Pennsylvania.[1]

16. Palæanatina solenoides Hall (?) ------------------------------ (rr)

A single specimen, which looks like a small one of this species.

[1]North Am. Index Fossils. Vol. I, 1909, p. 526.

17. Palæoneilo sp. -- (rr)
A broken and imperfect specimen.
18. (?) Aviculopecten sp. -- (rr)
A broken specimen.

The above list of species from the upper part of the Chagrin formation in Brandywine Creek supports the correlation of these beds with the Chemung formation of New York, and furnishes evidence for such correlation in addition to that mentioned in connection with the fauna of Chippewa Creek. Professor Williams in his list of fifteen southern diagnostic Chemung species considers the form a distinct species which is listed in the Brandywine Creek fauna as the variety *stigmata* of *Productella lachrymosa*. *Productella hirsuta* is also one of this diagnostic list of which the variety *rectispina* is found at Brandywine Creek, and if this variety is considered as representing the species on Professor Williams' list then five of the fifteen diagnostic Chemung species are present in this fauna, viz.: *Spirifer disjunctus*, *Productella lachrymosa*, *P. stigmata*, *P. hirsuta* and *Sphenotus contractus*. The proportion of identical species is still greater between this fauna and Professor Williams' two lists of twelve dominant Chemung species for western New York. The Brandywine fauna and the Chautauqua County list contain five identical species, viz.: *Spirifer disjunctus*, *Athyris polita*, *Productella lachrymosa*, *Ambocœlia gregaria* and *Strophalosia hystricula*.[1] The Genesee Valley section contains three identical species, viz.: *Spirifer disjunctus*, *Productella hirsuta*, and *Sphenotus contractus*; while *Ambocœlia umbonata* var. *gregaria* and *Camarotœchia* cf. *contracta* of Brandywine Creek are certainly very closely related to *A. umbonata* and *C. contracta* of the Genesee valley list. The presence of one-third of the list of southern diagnostic Chemung species and nearly one-half of those of western New York in the Brandywine Creek fauna taken in connection with the fact that nearly all the other species are either confined to this formation or only occur infrequently in rocks of other age is strong evidence for the correlation of the upper Chagrin with the New York Chemung.

In the broader valley below the gorge a well was drilled, a partial record of which was furnished the writer by Mr. O. H. McRoberts. From the mouth downwards it passed through 70 feet of blue clay, 45 feet of quicksand, 5 feet of coarse gravel, and then shale of different kinds to a depth of 800 feet. It was also reported as a good gas well for that section. The mouth of this well was below the top of the Chagrin formation, and after the Quaternary deposits were penetrated the remainder of it was entirely in the Chagrin formation. In the autumn of 1906 another well was drilled which was located in the valley above the fall and a few rods above the highway. Mr. McRoberts has also kindly given

[1]Bull. U. S. Geol. Survey, No. 210, p. 86.

the writer the following record of the first 150 feet of this well, which was drilled during his presence: "Earth 7 feet; Berea grit, 35 feet; blue or gray shale which was soft and would cave some, with water in hole, 50 feet; black shale 15 feet and the remaining 43 feet blue shale, which I suppose you call Erie shale." In the above record, the 50 feet of blue or gray shale represents the Bedford formation, with practically the same thickness as obtained by leveling in the gorge section; while the 15 feet of black shale represents the Cleveland.

Mr. McRoberts also sent me a few samples of the drillings from this well which give the following section:

Well Section at Brandywine Falls.

No.	Description of sample.	Thickness. Feet.	Depth. Feet.
1.	*Berea grit.* Sample composed almost entirely of rounded grains of white quartz of moderate coarseness	7–27	27
2.	Sample composed almost entirely of moderately sized chips of rather fine-grained sandstone, the grains of which are largely fine quartz sand. Looks as though it might come from a somewhat shaly zone. No effervescence	27–35	35
3.	Sample about like that of No. 1. Composed almost entirely of grains of rounded white quartz	35–38	38
4.	Composed almost entirely of grains of rounded quartz sand; but finer than those of Nos. 1 and 3. It is somewhat calcareous, so that there is at first a strong effervescence in cold HCl. This effervescence does not last long, however, and a large residue is left after the effervescence ceases. The base of this zone is probably the base of the Berea grit, in which case the thickness of the formation—35 feet—is exactly the same as that given in the letter from Mr. McRoberts	38–42	42
5.	*Chagrin formation.* Soft, bluish, argillaceuos shale, with white streak. Some of the chips are of considerable size, while part of the material is very fine. No effervescence in cold HCl. Sample labeled as from a depth of 500 feet	----	500

Above Brandywine Falls, on the northern side of the creek, the rocks are partly covered for some rods until in the pasture an outcrop of a stratum of buff, as weathered, bluish-gray on fresh fracture, compact sandstone 11½ inches thick, is reached. Below the sandstone partly exposed on the bank are soft, bluish-gray, argillaceous shales.

A little farther up the stream, and above the railroad bridge, is a cliff on the northern bank some 60 feet high. Near the foot of the cliff the stratum of fine-grained, bluish-gray sandstone is shown; which by the barometer is 20 feet higher than the top of the massive Berea.

At low water this sandstone is well shown all along the foot of the cliff just above the railroad bridge; and on this bank it is in a single layer 13½ inches thick. At low water, on the deepest part of the bank, fully 4 feet of blackish shale, which is rather argillaceous and soft, is shown beneath the sandstone. This shale probably represents the upper part of the Sunbury and the overlying stratum the Aurora sandstone. The interval between this sandstone and the top of the massive Berea is apparently greater than at most localities; but it is not certain that it is as great as indicated by the barometer. There is a covered interval of 5 feet between the top of the massive Berea grit and the exposed Sunbury shale on the highway to the south of the falls, a part or all of which perhaps belongs in the Berea. This perhaps leaves only some 15 feet of shale or less between the two sandstones. Succeeding the sandstone is a high bank of bluish-gray to blackish, soft argillaceous shale 55 feet in height, which belongs in the Brecksville. The shale is mainly bluish-gray in color and the entire bank is composed almost completely of soft shale, which makes a smooth sloping bank of dark color.

There are not infrequently banks of the soft Brecksville shale as the creek is followed up stream, and perhaps one-half mile above the first bank of this shale, in a small run from the western side, is apparently the base of massive buff to bluish-gray sandstone. This ledge of sandstone barometrically is 115 feet higher than the top of the Aurora sandstone at the lower cliff and it may be followed along the bank for a considerable distance.

Still farther up the creek the western bank shows the transition from the Brecksville shale into the superjacent sandstones. From the creek level up there are 15 feet composed mainly of shales which are rather bluish and arenaceous as a rule, with an occasional thin sandstone, as well as a slightly calcareous layer which weathers to a rusty color and resembles lithologically to some extent the calcareous layers in the Chagrin formation. These shales are succeeded by thin-bedded, bluish-gray sandstones which alternate with thinner layers of bluish shale, and this zone passes above into thicker bedded and more massive sandstone. The rock, however, of the thin-bedded sandstone and shale zone is mainly sandstone and its base was considered as defining the top of the Orangeville formation. The upper shales of the Brecksville are bluish-gray, more sandy, and consequently tougher than the middle and lower ones, so that there is something of a transition from it into the overlying sandstones. The transition is rather more gradual in this section than in some of the others studied; but the writer would draw the line of lithologic division where the sandstones begin. Some of the thin flaggy layers in the lower part of the sandstone contain fossils, of which *Productus* is the most common, but species of *Camarotœchia*, *Orbiculoidea* and Pelecypods occur. The apex of the brachial valves of the specimens of *Orbiculoidea* from the lower part of these sandstones

is more eccentric than in *O. herzeri* Hall and Clarke. The specimens were compared in the American Museum with types of *O. newberryi* Hall from Cuyahoga Falls, Ohio, with which they agree. Fossils, especially *Productus*, also occur in the thin sandstones and sandy shales of the transitional beds and this fauna allies these transitional layers with the sandstone rather than with the Orangeville formation.

The sandstones at this locality apparently correspond stratigraphically and resemble to a considerable extent lithologically the Sharpsville sandstone, which succeeds the Orangeville shale on the Ohio-Pennsylvania line, with which terrane the writer correlates them. The thickness of the Sunbury shale and Aurora sandstone is apparently not far from 15 feet, although there is a possibility that it is as great as 21 feet. This added to the 115 feet of Brecksville shale gives a probable thickness for the Orangeville formation of 130 feet; which may, however, be as great as 136 feet.

Some distance farther up the creek, and by the barometer 10 feet above the base of the Sharpsville sandstone, is a small cascade over the thick layers in the lower part of this sandstone. This locality is not far below Little York on the A. B. C. Division of the Electric Railroad. On the eastern side of the creek at this locality is a bank of about 15 feet, composed of bluish-gray sandstone alternating with some bluish shale. The highest outcrop seen on the creek is in the pasture not far above the electric railroad where a stratum of the bluish-gray sandstone occurs, some 20 feet higher than the cascade. The greater part of the Sharpsville member is a sandstone rather than a shale, as in some of the other localities in the Cuyahoga basin, with a thickness of at least 30 feet.

Since the above description was written the channel of Brandywine Creek through the Sharpsville sandstone has been deepened by blasting. This portion of the section was reëxamined and the following section of the Sharpsville member was obtained:

Section of Sharpsville Sandstone on Brandywine Creek.

No.		Thickness. Ft.	In.	Total thickness. Feet.
8.	*Sharpsville sandstone.* Bluish-gray sandstone, much of it weathering to a reddish or brownish color, and some layers are slightly calcareous. It is a fairly massive sandstone, with shale partings, and is fossiliferous, probably *Productus* and Pelecypods being the most abundant. The upper part of this zone forms the top of the southern bank below the Electric Road and highway	8	10	$34\frac{2}{3}$
7.	Thick sandstone layer, which varies in thickness from 1 foot 8 inches, at upper end of cliff, to 2 feet 1 inch	2±	--	$25\frac{5}{6}$

No.		Thickness. Ft.	In.	Total thickness. Feet.
6.	Rather thin-bedded sandstones, alternating with shales; but the sandstones predominating in thickness. Fossils, as *Productus* and *Orbiculoidea* are fairly common. Base of marked sandstone zone	7	8	$23\frac{5}{6}$
5.	Thin, bluish sandstones, alternating with bluish, arenaceous shales, which have the greater thickness	10	8	$16\frac{1}{6}$
4.	Second thin, bluish sandstone, which varies in thickness from $\frac{3}{4}$ of an inch to 4 inches	--	3±	$5\frac{1}{2}$
3.	Bluish, slightly arenaceous shale	5	1	$5\frac{1}{4}$
2.	Basal sandstone of Royalton formation; bluish to rusty colored as weathered, which varies in thickness from 1 to 2 inches	--	2±	$\frac{1}{6}$
1.	*Brecksville shale.* Soft, argillaceous, bluish-black to black shale			

The higher sandstones are exposed for some rods along the stream above the highway and Electric Road; but apparently no higher layers stratigraphically are shown than occur in the upper part of the cliff a number of rods below the bridges. The considerable amount of sandstone thrown upon the bank when the creek channel was deepened, as well as the greater thickness of rock exposed in place, afforded an excellent opportunity for searching for fossils in the Sharpsville sandstones at this locality. A number of species was obtained; but the list and notes are not yet ready for publication.

The upper valley of the Brandywine, to the southeast of Little York, is low and marshy, with little prospect of any outcrops of Carboniferous rocks. On the hill, however, $1\frac{1}{4}$ miles southeast of Little York, at only a short distance southeast of Town Line stop on the A. B. C. Electric Railroad, is an outcrop of the Sharon conglomerate. It is located to the southeast of the stone house that was built of rock quarried from this ledge. The rock is a coarse-grained sandstone and conglomerate which contains numerous quartz pebbles. The pebbles are mostly of white quartz, but there are some of rose and perhaps also of smoky quartz. The largest ones are the size of hen's eggs and well rounded; but not lenticular in shape. The thickness from the base to the top of the exposed Sharon is about 20 feet. Springs occur at various points along the base of the outcrop, showing the importance of the Sharon as a water-bearing formation. A single reading of the barometer gave an interval of 195 feet from the base of the outcrop of Sharon conglomerate to the top of the massive Berea grit on the bank at Brandywine Falls, $1\frac{1}{4}$ miles to the west. Prof. George F. Lamb, who first called

the writer's attention to this outcrop of the Sharon conglomerate, reported that the interval from the base of the Sharon conglomerate to the top of the outcrop of Sunbury shale at the old mill, had been leveled, giving a thickness of 195⅔ feet.[1] This indicates that the interval from the base of the outcrop of Sharon conglomerate down to the base of the outcrop of Sunbury shale, and at about the top of the Berea formation is 190 feet by the barometer and 201 feet as leveled. Subtracting the 131 feet of the Orangeville formation from the 201 feet of this interval leaves only 70 feet for the Royalton formation, which is probably not enough, since the topographic map indicates that the interval from the base of the Sharpsville sandstone, on the creek below Little York, up to the base of the Sharon outcrop, is between 80 and 90 feet or more. A single reading of the barometer gave 70 feet for the covered interval from the top of the Sharpsville sandstone cliff, on Brandywine Creek, below the bridges, to the base of the exposed ledge of Sharon conglomerate. This indicates a thickness of nearly 105 feet for the Royalton formation at this locality.

The following diagrammatic section will show the general thickness of the formations on Brandywine Creek, so far as they were studied, with the continuation to the top of the Sharon outcrop on the hill southeast of the Town Line stop:

General Section from Hill near Town Line Stop down Brandywine Creek.

424′		Top of outcrop southeast of Town Line stop	
	20′	Sharon conglomerate	
404′			
	70′	Covered	Royalton formation, 105 feet
334′			
	35′	Sharpsville sandstone	
299′			
	115′	Brecksville shale	Orangeville formation, 131± feet
184′			
	1′	Aurora sandstone	
183′			
	15±	Sunbury shale	
168′			
	39⅓′±	Berea grit	
128½′			
	48′	Bedford formation	
80½′			
	15½′	Cleveland shale	
65′			
	65′	Chagrin formation	
0′		Lowest outcrop visited	

[1]Letter of May 2, 1910.

Section West of Boston Mill.—Boston or Boston Mill is a small village located on the Cuyahoga River in the northwestern part of Boston Township. It is situated about 4 miles east of south of Chippewa Creek near Brecksville Station, and about 1½ miles north of Peninsula. A stream known as Granny's Run enters the river from the west, a short distance below this village, which gives an interesting section of the formations found in the northwestern part of this township. The following section was measured along this stream:

Section of Granny's Run.

No.		Thickness. Feet.	Total thickness. Feet.
7.	*Royalton formation.* On the bank, in the upper part of "the Gulf", are ledges of buff to bluish, fine-grained sandstones, alternating with buff to bluish, arenaceous shales. The second layer above the base as exposed on the southern bank is a foot thick. On the northern bank, probably at a point a little west of the township line, the barometer gave 45 feet from the lowest outcrop of sandstone to the highest. There is not, however, a continuous outcrop up the steep bank, since more or less of the rock is covered. These sandstones are believed to represent the western continuation of the *Sharpsville sandstone* of northwestern Pennsylvania. Beneath the sandstones is apparently a zone of gray to bluish, arenaceous shale, the thickness of which was not measured	45	301
6.	*Brecksville shale.* Soft, black to bluish-black shale, several banks of which are shown, that range in height from 6 to nearly 25 feet. The barometer gave a thickness of 75 feet for the interval from the lowest outcrop of black shale on the run, up to the lowest sandstone	75	256
5.	Covered interval	40	181
4.	*Berea grit.* Exposed on banks and in bed of run, forming a fall some rods below the highway and farm house. It is composed of coarse grains of quartz sand, and is massive. From the base of the Berea in the fall, to the highest outcrop on the southern bank, is 16 feet by level, or 20 feet by barometer. The Berea was formerly quarried to some extent at this locality, for either the canal lock or dam in the river at Boston Mill.	16	141
3.	*Bedford formation.* The upper part of the formation is well shown in the fall below the Berea grit. This part consists of thin-bedded, fine-grained sandstones, alternating with thin zones of blue, arenaceous shale. Some of the layers of sandstone are ripple-marked. On the southern bank of the run, some rods below the fall, is a sandstone zone, the top of which is 7± feet below the top of the formation. At this locality the following section was measured in the streamlet that enters the run from the south:		

No.		Thickness. Feet.	Total thickness. Feet.
	Upper zone of compact, blue sandstone, 4 feet 10 inches. Blue, arenaceous shales, 4 feet 2 inches, with some thin sandstones. Lower zone of blue, compact sandstone, some of which is slightly calcareous. Layers in upper part ripple-marked. The lower layer is 13 to 14 inches thick, very hard and compact, with a crystalline-like texture. Total thickness of zone, 13 feet 4 inches. Below the sandstone zone the formation is composed of blue, arenaceous and argillaceous shales, with an occasional thin layer of sandstone, some of which are of concretionary, lenticular structure. The barometer gave a thickness of 40 feet for this lower interval	60	125
2.	*Cleveland shale.* Composed mainly of slaty, even, rather coarse until weathered, layers of black shale. The lower 5 to 8 feet is rather coarse shale, and some of it a little sandy. The entire formation is shown on the northern bank between the old dam and fall. On this bank the line of contact between the Cleveland and Chagrin is sharp and clearly marked. By leveling up this bank a thickness of 15 feet was obtained for the Cleveland shale	15	65
1.	*Chagrin formation.* Composed of blue shale, with some layers of sandstone, the thickest ones in the cliff above the brink of the fall. The lowest outcrop noted is on the southern bank above lower dam or spillway, and not much higher than the paper mill at Boston Mill	50+	50

Probably the most marked feature in the above section is the thinness of the Berea grit, which is apparently not much greater than 16 feet; while the same formation on Slipper Run, near Peninsula, a little more than a mile to the south, has a thickness of about 45 feet. The Cleveland shale is also rather thin in this region, since it is only 15 feet on Granny's Run and thins to less than 7 feet on Slipper Run.

On the western side of the Cuyahoga River, not far above Boston Mill, is a high and conspicuous bank of the Chagrin formation.

Boston Ledges. — These well known and picturesque ledges of the Sharon conglomerate in Boston Township, which adjoins Northfield Township on the south, is the next locality studied south of Brandywine Creek on the eastern side of the Cuyahoga River. A high cliff of the conglomerate appears here composed mainly of a coarse sandstone to grit, containing some pebbles. Near the base of the cliff there is frequently a layer of coarse conglomerate of some thickness in which the pebbles are large. The joints parallel to the face of the cliff facilitate its breaking down, and there are numerous large blocks on the hill slope below the cliff which have broken off from it. In several cases two of these blocks have fallen so that the tops rest together, while the bases are detached, forming grottoes. There are also not infrequent caves formed by the joints where they are roofed over by the upper lay-

ers, a very picturesque locality, which is readily reached by the A. B. C. Division of the Electric Railroad from either Cleveland or Akron. By barometer about 55 feet of the Sharon conglomerate is shown, 33 feet of which may be seen in the cliff at one of the steep faces. This is shown in the following section:

Section of Boston Ledges.

No.		Thickness. Feet.	Total thickness. Feet.
3.	Mainly coarse sandstone to grit, containing some pebbles	28	55
2.	Coarse conglomerate at base of steep cliff	5	27
1.	Partly covered, but conglomerate shown to spring. The underlying rocks are concealed, so that the base of the Sharon conglomerate was not determined in case it extends to a lower horizon	22	22

The above ledges were first studied by the writer in 1901, after which the above description was written. They were again visited in 1907, when it was found that the Lake Erie and Pittsburgh Railroad was being built through the front of the ledge and that its beauty had nearly been destroyed. This locality will no longer be attractive for picnics or excursions, which is to be regretted since the State contains only too few attractive localities for such outings. As stated above, the upper part of the conglomerate is mainly a grit or very coarse-grained sandstone containing some quartz pebbles; but the lower portion is much coarser. At this time the barometer gave 50 feet from the base of the lowest outcrop of the conglomerate to its top as exposed in the woods above the railroad.

Boston Run Section.—The Lake Erie and Pittsburgh Railroad crosses a branch of Boston Run only a short distance south of the railroad cut through the Boston ledges. In the small gully near where the railroad crosses it is an outcrop of blue sandstone. This stratum is not far below the base of the Sharon conglomerate, for the barometer with an interval of nearly two hours between the readings gave a difference of only 15 feet.

Section on Boston Run.

No.		Thickness. Feet.	Total thickness. Feet.
8.	Covered interval of 15 feet or more to *Sharon conglomerate*	15+	136
7.	Just below the railroad track is a layer of blue, fairly fine-grained sandstone, 9 to 10 inches thick. Just a little lower is another blue, compact, massive sandstone, 10 inches or so in thickness, which is slightly calcareous. Two compact, blue, calcareous sandstone layers, each about 10 inches thick, separated by arenaceous shales, were seen. No fossils were noted. The rocks of this zone consist largely of arenaceous shales	20	121

No.		Thickness. Feet.	Total thickness. Feet.
6.	Mainly covered interval	20	101
5.	At the top, an arenaceous layer to thin sandstone, 2 inches thick, with blue shale below, which is mainly argillaceous. Partly covered; but 15 feet below the thin sandstone is blue, soft, argillaceous shale, as shown in the run	15	81
4.	Mostly covered interval	45	66
3.	Thin layer of sandstone, with bluish-black shale, below which it is very argillaceous. Partly covered interval	10	21
2.	Bluish sandstone layer, about a foot thick, splitting up into thin layers. A little lower it appears as a pretty thick, massive sandstone	1	11
1.	About 5 feet below the sandstone, 3 feet of soft, argillaceous shale of blackish color is shown on the branch, and 5 feet lower, on Boston Run, is black, fissile shale. On this run the lowest bluish sandstone noted on the branch makes a small fall; below which are 10 feet of soft, blackish shales, containing an occasional very thin sandstone layer. About 5 feet of soft shales, with thin sandstone layers, are shown on the bank of Boston Run, a little above the sandstone	10	10

In the above section the rocks above the blue sandstone of zone No. 2 apparently belong in the Royalton formation, while the bluish-black shale below is in the Brecksville. This correlation is not altogether satisfactory, since it seems to leave too thin an interval down to the Chagrin formation, which is apparently shown on the bank of this run where it is crossed by the highway just north of Peninsula. The intervening rocks, however, are covered by glacial and alluvial deposits and the writer was compelled to leave the section in this rather unsatisfactory condition.

Rather more than one mile south of the Boston ledges are the Ritchie ledges to the south of Boston and Haskell runs. The base of the ledges near the spring is barometrically 265 feet higher than Peninsula station or the outcrops on Boston Run at the river highway bridge. The outcrops of the Sharon conglomerate to the south of Haskell Run are known as the Thompson and Ritchie ledges, and form a steep hill as shown on the topographic map. The rock is generally a conglomerate; but there are layers in which the pebbles are much more abundant than throughout the mass of the rock. The pebbles are mainly white quartz, although there is an occasional one of rose quartz. The faces of some of the cliffs and blocks show good examples of differential weathering, as is frequently the case with the weathered cliffs of the Sharon conglomerate.

Slipper Run Section.—This stream rises on the high ground

to the west of Peninsula and flowing easterly enters the Cuyahoga River at the northern edge of that village. The highest outcrops noted occur in the run just south of the highway and house of Mr. J. B. Kennedy, rather more than two miles west of Peninsula. The following section is shown along this run from the locality just mentioned in descending it to the river:

Section on Slipper Run.

No.		Thickness. Feet.	Total thickness. Feet.
10.	Shales and thin sandstones, which contain poorly preserved fossils. About 5 feet below the top, a layer of sandstone, in which fossils are better, although still imperfectly preserved, comprising *Spirifer* and two or three other species. Then bluish shales and thin-bedded sandstones are shown for 20 feet or more down a small branch of the run	25	398
9.	Covered interval, with frequent beds of boulder clay	105+	373
8.	Massive, bluish, rather fine-grained sandstone, about 5 feet shown. These sandstones are probably at or near the base of the Royalton formation	5—	268
7.	Covered interval of about 13 feet	13	263+
6.	Blackish, argillaceous shale in the bed and on the bank of the run, a mile or so above the Independent quarry. Perhaps a little more than 2 feet is shown, which is probably in the Brecksville shale.	2	250½
5.	Covered interval, with frequent low banks of boulder clay.	105	248½
4.	*Berea sandstone.* Top of massive sandstone in quarry of Independent Stone Co., on road west of Peninsula. The top of this quarry is covered by boulder clay and till, and the top of the massive stone in it is about 5 feet higher than the top of the exposed massive stone on the northern side of the road. On the southern wall of the quarry, 32 feet of massive, coarse-grained rock was measured. One of the quarrymen said that in one corner of the quarry they have gone down 46 feet in this stone, and a core drilling in the stream valley above the quarry, gave the same thickness for the sandstone. Just below, and north of the highway culvert, is an outcrop of coarse-grained quarry stone similar to that of No. 16, of the Peninsula quarries, 7 feet of which is exposed. From the base of the Berea as shown in the stream, to the highest exposure in the quarry, one barometer gave 40 feet and the other 45 feet. The lower portion of the Berea forms a cascade in the stream, and shows the following zones from the base up: a ⅔-inch sandstone layer, then 4 inches of blue, ripple-marked shale, covered by 1 foot of heavy sandstone, followed by 8½ inches of arenaceous shale, with 1½ feet of heavy sandstone above, then a 4-inch parting of shale to shaly sandstone, capped by a stratum of heavy sandstone, 3 feet 9 inches thick. From the		

No.		Thickness. Feet.	Total thickness. Feet.
	base of the Berea sandstone, to the top of a somewhat concretionary layer shown on the northern bank, is 14 feet by the hand-level	45±	143½
3.	*Bedford formation.* Near the top of the formation is a compact, fine-grained, blue sandstone layer, containing ripple-marks. The formation is composed mainly of bluish shales, with thin sandstone or calcareous partings. The lower 10 feet or so of the Bedford consists of bluish shale zones, from 3 inches to about a foot in thickness, separated by thin layers of sandstone, from one-half to one inch in thickness. The thickness as leveled by Mr. Morse is 42 feet, and 45 feet by both barometers	42	98½
2.	*Cleveland shale.* The base of the shale is shown on the southern bank below the bridge, where the lower part has a bluish color, and is so sandy that it is lithologically unlike the typical Cleveland shale, and splits up into rather large, coarse and rough pieces. Between 6 and 7 feet is shown on this lower outcrop. Above the highway, on the northern bank, the entire thickness of the shale is shown, which is only 6 feet 8 inches, and on account of the presence of arenaceous material, most of it is rather impure. A little farther up the stream the shale is shown on both sides of the run, resting on the Chagrin formation. On the northern bank, 5 feet is shown, but not the top. This shale forms the bed of the run for several rods, and its upper part is a purer black, fissile shale than the lower, more like the typical Cleveland, and at the top is a sharp contact with the overlying blue Bedford shale	6½+	56½
1.	*Chagrin formation.* It consists of the usual bluish shales, alternating with thin layers of sandstone, and according to the barometer, 50 feet is exposed to the river level	50	50

Peninsula Quarries.—Just above Peninsula, near the center of Boston Township, are large quarries in the Berea grit, operated by the Cleveland Stone Company. The stone was formerly extensively quarried at this locality and in the mill on the same property sawed into paving stone, sills, etc., while it was also cut and dressed for grindstones and pulpstones; but in later years the quarries have not been so actively worked. The stone is very massive as shown in the quarries, with the exception of the upper part of the walls in the southern ones, and is cut out in large blocks by the channelling machine and then sawed or dressed to the desired size. The section of the rocks at this locality is given below, which begins at the bottom of the canal and extends to the top of the southern quarries:

Section from Canal to Top of Cleveland Stone Company Quarry No. 16, at Peninsula.

No.		Thickness. Ft.	In.	Total thickness. Feet.
11.	Till and soil to top of bank; upper portion gravelly and sandy, lower part blue clay.	11±	--	119
10.	*Berea formation.* Quartzose sandstone, with grains like Berea, but finer than those of zone No. 8; bluish-gray in color, with numerous grains of marcasite......	1	8	108--
9.	Mainly bluish, argillaceous shale; some of it is a little sandy, containing some fine quartz grains and a little is rather blackish in color	3	--	106¼
8.	Coarse-grained sandstone, like the Berea...	--	9	103¼
7.	Mainly arenaceous shale..................	1	7	102½
6.	Coarse-grained, bluish-gray sandstone like the Berea	--	4½	101—
5.	Arenaceous, grayish shale	1	5	100½
4.	Top of massive stone in quarry. The upper part of the highest course contains nodules of iron pyrites or marcasite, similar to what is usually found in the upper surface of the Berea grit. There are also a few white quartz pebbles near the top. The greater part of the quarry stone is very coarse-grained, and bluish-gray in color; in this respect quite like the Cussewago sandstone of western Pennsylvania, only more compact. In this quarry, five courses are worked, with the following thicknesses counting from the top downward: Course No. 5, 8 feet 2 inches; Course No. 4, 7 feet 3 inches; Course No. 3, 8 feet; Course No. 2, 7 feet 8 inches, and Course No. 1, which is the lowest one worked, and apparently extends nearly, or quite, to the base of the sandstone, 8 feet, making a total thickness of 39 feet 1 inch by tape measure for the stone that is quarried. All of the quarry stone is coarse-grained, noticeably more so than in the quarries at Berea. In an older part of the quarry farther to the north, five courses were also shown, with the following thicknesses from the top down: Course No. 5, 8 feet; Course No. 4, 7 feet; Course No. 3, 7 feet 6 inches; Course No. 2, 6 feet, and Course No. 1, which was not worked and is partly covered, 8 feet 3 inches to the base of the Berea grit. This section gave a total thickness for the mas-			

No.		Thickness. Ft.	In.	Total thickness. Feet.
	sive portion of the Berea grit of $36\frac{3}{4}$ feet, the upper $28\frac{1}{2}$ feet of which was quarried.	39	1	99+
3.	*Bedford formation.* In the gully, just below the blacksmith shop, about 5 feet of blue shale, with thin layers of bluish sandstone is shown. The top of this zone extends nearly or quite to the base of the Berea grit. From its top, as shown in the gully, to the top of the massive quarry stone, is 40 feet by the barometer, while the face of the quarry wall gave 39+ feet by tape line	5±	--	60
2.	The slope of the bank below is mostly covered. If the thickness of the Bedford remains the same as in Slipper Run, about one-half mile to the north, where it is 42 feet, then it is about 37 feet from the base of zone 3 to the base of the Bedford formation	37	--	55
1.	On the bottom of the canal, at the base of the slope, 56 feet below the base of the Berea, bluish shale was shown in 1901. This is apparently some 14 feet below the base of the Bedford formation, and in the *Chagrin formation.* Again, on the eastern bank of the Cuyahoga River, a little below the railroad bridge, and about opposite the southern end of quarry No. 16, is an outcrop of bluish shales and sandstones. This outcrop is 50 feet below the top of the Bedford at the blacksmith shop, and therefore apparently in the Chagrin formation. About 10 feet is shown on the river bank. Near the base of the zone is a 7-inch sandstone, and 2 or 3 feet higher is another one, a foot in thickness. The Cleveland shale, between the Bedford and Chagrin formations, which in the Slipper Run section is only $6\frac{1}{2}$ feet thick, was not seen, and probably it is in the above noted covered zone. This seems to show that there is about 18 feet of the Cleveland shale and Chagrin formation down to the level of the Cuyahoga River, approximately the upper 8 feet of which is covered	18±	--	18

In the above section the Berea formation extends from the base of No. 4 apparently to the top of No. 10. This zone is covered by till and if the rocks directly succeeding No. 10 were shown perhaps the top

of the formation might be carried a little higher. The thickness of about 48 feet, however, agrees closely with that of the 45 or 46 feet obtained for this formation in Slipper Run and the Independent Stone Company quarry about one-half mile to the north. A view of quarry No. 16 of the above section is shown in Plate LI, B, in which Mr. Morse stands opposite course No. 3.

Sections North of Everett.—About one mile north of Everett, or one and one-fourth miles southwest of the Peninsula quarry No. 16, a stream crosses the railroad track at the first highway crossing of the railroad to the south of Peninsula. The hill here runs up steeply from the river valley for more than 200 feet, and this small stream has in general cut through the soil and till to the bed rocks, which are well exposed along a considerable portion of its course.

Section Along the Stream One Mile North of Everett.

No.		Thickness. Ft.	In.	Total thickness. Feet.
15.	*Royalton formation.* Blue, argillaceous shale, with numerous thin to concretionary layers of compact, bluish limestone, ½ to 1 inch in thickness, which weather to a rusty color on the surface and project from the shale banks. The top of these shales is found at about the head of the gully	9	--	161½
14.	Two layers of compact limestone, each about ¾ of an inch in thickness, separated by blue shale	--	3	152½
13.	Blue shale	--	9	152¼
12.	Blue shale, alternating with thin sandstone at the top of this zone. The sandstone of the middle portion is thicker than that of the upper and lower parts of the zone, and is rather massive. The basal portion of the zone consists of thin, blue sandstones, which weather to a buff color, some of the layers 6 inches thick, alternating with bluish shales. The zone is mainly a sandstone one	18	--	151½
11.	Arenaceous shale to thin sandstone, marking the base of the Royalton formation	2	--	133½
10.	*Brecksville shale.* Blackish, soft, argillaceous shales to the base of the overlying arenaceous deposits. The lower part of the zone composed of soft, black, argillaceous shale	90	--	131½
9.	*Aurora member.* Small fall in run, formed by a blue, rather fine-grained sandstone, which on weathering tends to split up into thin layers	1	6	41½

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
8.	Blackish, soft, argillaceous shale. On one bank, 3 feet 4 inches in thickness, and on another, 3 feet 8 inches	3	6	40	
7.	Thin sandstone layer, 1 inch thick, blue and fine-grained	--	1	36½—	
6.	*Sunbury shale.* Blackish shale, with a sandy parting 5 feet 4 inches above the base. The lower portion of the member is a clear black shale, containing numerous specimens of *Lingula melie* Hall. *Orbiculoidea herzeri* Hall and Clarke also occurs, and a fragment of a *Conularia* was found. The shale in general is strongly bituminous and fissile, splitting into thin pieces	11	3	36⅓	
5.	*Berea formation.* Blue, rather fine-grained sandstone, which splits into somewhat thin layers, the upper portion full of marcasite	2	--	25+	
4.	Bluish, argillaceous shale	--	9	23+	
3.	Thin-bedded, bluish sandstone	2	3	22⅓	
2.	Coarse-grained, massive, blue layer of sandstone	1	7	20+	
1.	Rather thin-bedded, bluish-gray sandstone, alternating with blue, arenaceous shales. Numerous layers are ripple-marked and others contorted, similar to concretionary layers. Below the base of this sandstone zone is a covered interval of about 25 feet, when an outcrop of the Bedford bluish, argillaceous shale is reached, not far above the railroad track	18	6	18½	

In this gully only 25 feet of the Berea formation is shown; but it is probable that the base of the formation occurs lower in the covered interval. The sandstones are decidedly finer grained than those in the quarries a mile and a quarter to the northeast and the layers are not thick and massive; but on the contrary there is much arenaceous shale. The blue, fine-grained sandstone at the top of the Berea and the superjacent black, fossiliferous Sunbury shale show conclusively that the arenaceous shales and thin sandstones overlying the massive quarry stone in quarry No. 16 belong in the upper part of the Berea formation. The rapid change in texture from the massive layers in quarry No. 16 to the much thinner and even shaly layers and shales in this gully is also to be noted. In this section the entire Orangeville formation is shown, from No. 6 to 10 inclusive, with a thickness of 106½ feet, or as given by the barometer of 110 feet. This is overlain by the Royalton formation, the lower 30 feet of which is shown, and the lower sandstones probably represent the westward extension of the Sharpsville sandstones from Pennsylvania.

About one-fourth of a mile south of the stream just described is a steep bank on the western side of the railroad in which the basal deposits of the Berea formation are well shown together with the upper 20 feet of the Bedford. This portion of the Bedford is composed principally of shales; but there are also some layers of thin sandstone.

Furnace Run and Branches.—Richfield Township lies directly west of Boston and south of Brecksville townships. Dr. Newberry reported that in the upper part of the Cuyahoga shale "at Richfield, Summit County, immense numbers of fossils are found."[1] The above reference was not very definite; but some of the residents stated that the collectors obtained most of their fossils from Furnace Run. One of the principal places mentioned on the run is near the iron bridge about four miles west of Peninsula. This locality according to the barometer, appears to be about 60 feet above the top of the Berea grit. About 100 yards below the bridge are exposures of blue, argillaceous shales, which break up into very small pieces as they weather. This did not appear to be fossiliferous to any extent and resembles the Brecksville shale. Nearer the bridge are numerous blocks of somewhat calcareous rock, loose in the brook, which contain a good many fossils. Some of these are of concretionary structure and are evidently washed out of the higher shales and brought down by the stream. The eastern edge of the Sharon conglomerate on the Newberry "Geological Map of the State of Ohio" of 1879 was represented as passing through Richfield; but it was not seen until in a small stream one-half mile west of West Richfield. This outcrop according to a single reading of the barometer is some 250 feet higher than the top of the Berea grit and ledges of the Sharon conglomerate also occur to the west of West Richfield.

On the southern line of Richfield Township at a three corners two and one-fourth miles west of Everett is a country church. The hills to the west of Furnace Run in this region are steep. The church just mentioned is about one and one-half miles west of the run and the difference in altitude is between 410 and 425 feet according to the barometer, or about 420 feet by the topographic sheet. To the north and south of the town line road running eastward from the church are streams tributary to Furnace Run, some of which have cut rather deep gullies. The older rocks, however, along this steep road, and to a considerable extent in the gullies, are concealed by drift and clay deposits.

A gully beginning about one-fourth of a mile north of the church was followed well down toward Furnace Run. The older rocks are shown but infrequently in it, the banks being composed largely of soil and blue boulder clay. The section of this gully is about as follows:

[1]Geol. Surv. Ohio, Vol. I, p. 212.

Section of Gully North of Town Line Road and Church.

No.		Thickness. Feet.	Total thickness. Feet.
8.	Covered interval from the church down to the first outcrop of Paleozoic rocks	140	300
7.	Thin-bedded sandstones; thickness not given, probably less than a foot	1—	160
6.	Covered interval	14	159
5.	Thin-bedded, blue sandstone, alternating with bluish shales. An exposure of about 3 feet. At the top is a calcareous layer, 4 to 5 inches in thickness, which weathers to a very rusty color, and is fossiliferous. It contains numerous crinoid segments, *Spirifer*, *Camarotœchia*, *Spirophyton*, and probably other fossils. A little lower is another calcareous layer, with partings nearly a foot in thickness, which contains numerous crinoid segments, *Spirifer*, *Grammysia* and other Pelecypods	3±	145
4.	Covered interval	22	142
3.	A slightly calcareous layer, which weathers to a rusty color, 2 inches in thickness. Bluish shales below which are thin, lenticular, calcareous layers, weathering to a rusty color. Some of the lower portion of this zone is covered; but it was not noted how much	20	120
2.	Bluish, calcareous layer, 8 inches thick, with *Spirophyton* markings. About 2 feet of bluish shales are shown below the calcareous layer, which are the lowest Paleozoic rocks seen in the gully. Low banks of blue boulder clay begin shortly below the shales	3	100
1.	Banks of soil and boulder clay, which extend down the gully as far as it was followed	97	97

The Paleozoic rocks shown in this gully apparently all belong in the Royalton formation. This conclusion is supported by the fact that in the first gully south of the town line road, some three-fourths of a mile farther south,the contact of the Royalton and Orangeville formations occurs some 75 feet lower than the lowest shales noted in this gully as may be seen on comparing the two sections with reference to the difference in altitude below the church. At his house, just below the church and three corners, Mr. Underwood reported the section of a well which was drilled for 65 feet in blue clay and then 7 feet deeper in shales and sandstones.

A run heads not far south of Mr. Underwood's house on the southern side of the town line road, and runs eastward nearly parallel with the road near the northern line of Bath Township until it enters a larger stream tributary to Furnace Run. This run has a rapid descent, and for part of its course has cut a rather deep gully in which the Paleozoic rocks are much better shown than in the gully to the north of the road. The section of this run is about as follows:

Section of Gully South of Town Line Road.

No.		Thickness. Ft.	In.	Total thickness. Feet.
16.	Covered interval from the church down to the first Paleozoic rocks	115	--	413
15.	*Royalton formation.* Thin, blue sandstones in run below Mr. Underwood's house. Lower, are buff, calcarous layers, containing *Spirophyton.* Part of the interval is covered	30	--	298
14.	Fairly heavy layers of sandstone, weathering to a rusty color, which alternate with bluish shale. Partly covered	15	--	268
13.	Rusty sandstone of some thickness, some of which shows ripple-marks, with blue shale below. Partly covered. Lower part of zone consists of bluish, arenaceous and argillaceous shales	40	--	253
12.	Layer of blue sandstone, weathering to a rusty color, 9 inches in thickness. Below are bluish, arenaceous and argillaceous shales, with thin, calcareous layers. Loose in the stream is a layer with cone-in-cone. Partly covered	35	--	213
11.	Layer of bluish sandstone, 10 inches thick. Below this one are layers of sandstone, alternating with blue shale	8	--	178
10.	Soft, argillaceous, bluish-black shales, with rusty, concretionary layers	29	--	170
9.	Bluish to buff, as weathered, compact sandstone	--	9	141+
8.	Blue shale	--	7	140½
7.	Massive, compact, blue to buff sandstone	2	--	139¾
6.	Bluish, arenaceous shales, alternating with thin layers of sandstone to brink of small cascade	2	9	137¾
5.	*Brecksville shale.* Soft, bluish to blackish, argillaceous shales, weathering to a rusty color as shown at the cascade and on the south bank for a few rods below the fall	15	--	135
4.	Covered interval	25	--	120
3.	Blackish to bluish-black, argillaceous shale, which is the lowest outcrop of Paleozoic rocks seen on this stream	5	--	95
2.	Covered by soil and boulder clay to bridge on east and west road over run	30	--	90
1.	Covered to level of Furnace Run	60	--	60

In the above section the writer does not remember whether zone 3 is exposed on the run parallel to the highway or whether it occurs on the larger one of which the former is a tributary.

The writer considers the zone of arenaceous shales and sandstones—No. 6 of section—forming the cascade in the small run as the basal one of the Royalton formation below which are the soft argillaceous, blackish to bluish-black Brecksville shales. This horizon, which is taken for the contact of the Orangeville and Royalton formations, is considered the same as the one to be described on Yellow Creek, three miles to the south. Overlying the Brecksville shale is fairly well exposed 163 feet of rocks, composed principally of bluish shales and thin blue sandstones alternating with bluish argillaceous and arenaceous shales, all of which is referred to the Royalton formation. The sections in the streams near Peninsula and on these tributaries of Furnace Run show that above the Brecksville shale is a thin sandstone zone which probably is the thinned western extension of the Sharpsville sandstone of western Pennsylvania. Then in ascending order for a considerable thickness there are bluish shales with thin layers of sandstone and also compact, thin impure layers of limestone. Still higher, perhaps, sandstone layers occur more frequently.

A broken down ledge of Sharon conglomerate occurs on the township line road one and three-fourths miles west of the above mentioned church. This locality is on the hill to the west of L. E. Andrews' house and is 20 feet or more, according to the barometer, lower than the church to the east. To the west of North Fork and two and one-fourth miles west of the church, the Sharon conglomerate makes a hill of some elevation at a three corners, since it rises rapidly for 125 feet or so from the elevation at the corners. This locality is nearly a mile east of Osborn Corners and the ledge is apparently a continuation of the well known Hinckley ledges two miles or more to the northwest in Hinckley Township.

Yellow Creek Sections. — Yellow Creek crosses Bath Township from west to east and enters the Cuyahoga River in the western part of Northampton Township near Botzum. These townships are directly south of Richfield and Boston townships, and the mouth of the creek is about 5 miles west of south of the quarries in the Berea grit near Peninsula. The general course of the stream is about parallel with that of Chippewa Creek, only it is some 12 miles farther south.

On the lower course of the stream are rather high banks which are composed of till and other glacial deposits. In the bed of the creek, however, just above the highway bridge at "the Pineries" is an outcrop of bluish-gray to bluish-black, soft argillaceous shale, which makes a small fall. This locality is about one and one-half miles from Botzum, and the lowest outcrops of the shale are between 50 and 55 feet higher than the railroad at that station. This shale continues up the creek for a few rods when a higher fall over layers of sandstone is reached. For about three feet below the base of the lowest thick sandstone the

blue shale alternates with thin blue sandstones from 1 to 2 inches in thickness. At the brink of the fall, and a little above, is a sandstone zone with some shale partings apparently over 2 feet in thickness; while a little farther up the creek 2 feet or more of blue fine-grained sandstone shows in its bed. As will be stated again, it appears to the writer that this sandstone zone is at the base of the Sharpsville sandstone, and that the fine, soft shales below are at the top of the Orangeville formation.

A little farther up the creek than the fall are rather high banks of bluish, arenaceous shales alternating with bluish thin-bedded laminated sandstone. The lower part of the first bluff on the southern side is covered, but well toward the top are apparently rather heavy sandstones. In the continuation of this bluff, which is apparently some 100 feet in height, the rocks of its lower portion are shown at the upper end of the gorge, where the stream bends sharply to the north, while a gully higher up the bank, which will be described later, enables one to study at close hand the upper rocks. The outcrops on Yellow Creek continue for a half mile or farther above the gorge where the last ones seen are blue shales and thin-bedded bluish sandstones, 45 feet higher than the lowest outcrops of shale. The creek was followed to the Bent Work Mill below Mr. E. E. Daniels', two and one-half miles above Botzum; but on the stream for a mile or so below the mill only banks of boulder clay and sandy deposits were seen.

The gully mentioned above in the cliff at the upper end of the gorge was examined, but the steep part of the bank below the fall was not reached for careful study. A section from the lowest outcrops on Yellow Creek to those one-half mile above its gorge and then up this gully has been constructed.

Section on Yellow Creek and Gully at Upper End of Gorge.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
10.	Buff to bluish, fairly thick-bedded sandstones near head of gully. These sandstones are separated by rather coarse, bluish to grayish shales, which alternate with them. Fossils are rather infrequent in this zone	20	--	175	--
9.	*Upper limestone.* Massive, very hard layer 9 inches in thickness, which is a blue, somewhat fossiliferous, impure limestone, that weathers to a very rusty color and resembles the upper one described, near North Royalton	--	9	155+	
8.	Rather coarse, arenaceous shales	2	7	154	4
7.	Layer of impure limestone, about 9 inches thick, but perhaps not quite so calcareous as upper one	--	9	151	9

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
6.	Rather coarse, bluish to bluish-gray, argillaceous and arenaceous shales, with an occasional thin, blue sandstone. There are also somewhat calcareous layers of concretionary structure, which weather to a rusty color, with lithology similar to the impure limestones above. Sandstone layers not much below the impure limestone contain numerous specimens of at least a few species. Nearly all of this zone is exposed and consists of the blue shale, alternating with thin sandstone layers	46	8	151	--
5.	*Lower limestone.* A stratum of impure limestone, more sandy than the upper ones, from 10 to 11 inches in thickness, which occurs in the midst of coarse, blue, argillaceous shale	--	10+	104	4
4.	Blue, rather coarse, argillaceous shale	20	--	103	6
3.	Thin-bedded sandstones are more prominent, alternating with blue shales. These sandstones form a cascade in the run, the top of which is probably 40 feet or more above the bed of the creek. Looking down the cliff from the brink of the cascade, it can be seen that for some distance it consists of bluish shales, alternating with thin-bedded sandstones. Perhaps the shales with the impure limestones above this fall might be separated formationally from those below it, in which sandstones, even if they do not predominate, are much more common than in the upper shales. According to the barometer, the top of the cascade is 38½ feet higher than the upper exposure seen on Yellow Creek, which is the interval covered by this zone	38	6	83	6
2.	Thin-bedded, blue sandstones, alternating with blue shales; upper exposures on Yellow Creek. The banks show bluish, arenaceous shales, alternating with bluish, thin-bedded, laminated sandstones. At the base, a zone of fairly thick-bedded, fine-grained sandstone	35	--	45	--
1.	About the upper 3 feet consists of blue shale, with layers of blue sandstone from 1 to 2 inches in thickness; lower part bluish-gray to bluish-black, soft, argillceous shale. This zone is probably the top of the Orangeville formation	10	--	10	--

A larger run than the one described above enters Yellow Creek from the south, just below the fall in that creek, and near the lower end of the gorge. Another section commencing with the lowest shales on Yellow Creek, and then following the run just mentioned, has been prepared and will now be described.

Section on Yellow Creek and Run Near Lower End of Gorge.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
14.	Highest exposures in pasture above highway bridge. Compact, fine-grained, laminated, blue sandstone, weathering to a buff color, which lithologically resembles the Sharpsville sandstone. An occasional layer is about a foot in thickness, but nearly all are much thinner, and alternate to some extent with blue shale. The lower part of the zone is shown on the bank below the bridge. Somewhat fossiliferous	30	--	191	--
13.	*Upper limestone.* The abutments of the highway bridge rest on top of this stratum. Blue, impure limestone the lower part of which is very fossiliferous	--	10	161—	--
12.	Shaly interval, sandy, part of it hard and apparently calcareous	2	10	160	--
11.	Layer of bluish, impure limestone	--	6	157	2
10.	At the top are 4 feet of soft, bluish shale, at the base of which is a calcareous, concretionary layer. Soft, blue shales predominate; but there are a good many layers of thin, blue sandstone and some calcareous, concretionary ones. At the base of this zone are several rather thin sandstone layers	56—	--	156	8
9.	*Lower limestone.* Somewhat sandy but calcareous stratum, 8 inches or more in thickness. The reading of the barometer on this stratum was almost identical with that of the lower limestone in the upper gully, and they are undoubtedly identical	--	8	100	8
8.	Mostly blue shale, of which the greater part is apparently soft and argillaceous. There is some arenaceous shale, however, and thin sandstone of concretionary layers	25—	--	100	--
7.	At about the top of the more conspicuous sandstones; but there is no clear and sharp line of division. The sandstones are thin-bedded, alternate with shale, and				

No.		Thickness Ft.	In.	Total thickness. Ft.	In.
	there is a considerable number of calcareous, concretionary layers. There are some fossils as small Spirifers	15	--	75	--
6.	Sandstone and slightly calcareous layer at the top of this zone. Laminated, thin-bedded, blue sandstones, alternating with blue shales	20	--	60	--
5.	Mainly bluish shales, containing numerous somewhat calcareous and rusty concretions. A decided shale zone	25	--	40	--
4.	Blue, compact, fine-grained sandstone, with an occasional thin shale parting. Somewhat calcareous, bluish concretions of rather large size occur in this zone	3	8	15—	--
3.	Shale	--	7	11	3
2.	Blue sandstone. Nos. 2, 3 and 4 occur almost at the mouth of this run, and they make the fall in Yellow Creek a rod or two above. The zone is almost 5 feet in thickness. It is thought that this zone represents the base of the *Sharpsville sandstone*	--	8	10	8
1.	About the upper 3 feet consists of blue shale, with layers of blue sandstone from 1 to 2 inches in thickness; the remainder of the shale is bluish-black, soft and argillaceous. These are the lowest shales seen on the creek, and they are exposed in its bed and banks from the bridge at "the Pineries" up to the foot of the falls a few rods above. This zone is thought to represent the top of the *Orangeville formation*	10	--	10	--

The measurement for the greater part of both of these sections was by barometer. The total thickness for the lower one, taken from readings in ascending, was 190 feet, which has been used in the above section. On descending the hill, during a shorter period of time than in ascending it, the readings gave 180 feet for the total thickness.

The outcrops of Carboniferous rocks on Yellow Creek unfortunately do not extend low enough to render it safe to correlate unhesitatingly the lower part of the above sections. The evidence, however, strongly favors correlating the lower ten feet of shale with the upper part of the Brecksville, the upper member of the Orangeville formation, and the superjacent sandstones with the basal ones of the Sharpsville. Lithologically this shale is very similar to the upper part of the Brecksville which on Chippewa Creek, twelve miles to the north, is capped by similar rather thick sandstones at the base of what is regarded as the western extension of the Sharpsville sandstone.

The top of the exposed Berea grit in the quarries at Peninsula is more than 103 feet above the bed of the canal, succeeding which is the Orangeville formation with a thickness of 115 feet on Chippewa Creek and about 128 feet on Brandywine Creek. The top of the shale referred to the Orangeville formation on Yellow Creek is about 6 miles southwest of the quarries near Peninsula, and between 60 and 65 feet higher than the railroad at Botzum. The railroad at Peninsula is probably about 10 feet higher than the bed of the canal, which would make the top of the Orangeville formation about 208 feet higher than the railroad at that village. This indicates a dip of about 24 feet per mile to the southwest, *providing* the top of the first shale on Yellow Creek is the top of the Orangeville formation.

The limestones which are called simply lower and upper in the above sections and the one at North Royalton have some lithologic resemblance to the Lower and Upper Meadville limestones of western Pennsylvania. Their stratigraphic position is also similar; but it is not considered that the evidence is strong enough to warrant their precise correlation.

In Cuyahoga and Summit counties there appears to be no difficulty in dividing the original Cuyahoga shales of Newberry into two formations on lithologic grounds of which the lower one is the Orangeville. It does not appear, however, that there is any very definite lithologic break that can be used for dividing this upper portion of the Cuyahoga terrane. It would appear on the basis of classification in the Cuyahoga basin that the Cuyahoga terrane of Newberry can readily be divided on lithologic grounds into two formations, but not more.

If the opinions advanced regarding the correlation of the Yellow Creek section be correct, then the exposures in the upper part of the lower run extend stratigraphically 30 feet higher than those of the section near North Royalton and from 170 to 180 feet higher than the top of the Orangeville formation. On Chippewa Creek the Orangeville formation is 115 feet in thickness and on Brandywine Creek from 125 to 130 feet. Consequently if the thickness of the Orangeville formation be added to that of the overlying rocks on Yellow Creek it will give a thickness of from 285 to 310 feet for the Cuyahoga terrane. Dr. Newberry gave the thickness of the Cuyahoga shales in Cuyahoga and Summit counties as from 150 to 200 feet,[1] which is apparently about 100 feet less than may be obtained on Yellow Creek. The thickness, however, of the Cuyahoga terrane varies decidedly within comparatively short distances in this region, due apparently to the unequal erosion of its upper surface.

Dr. Newberry gave the combined thickness of the formations in Cuyahoga County which are now generally referred to the Waverly series—the Bedford shale, Berea grit and Cuyahoga shale—as from

[1]Geol. Surv. Ohio, Vol. I, pp. 184, 210.

285 to 335 feet[1] and for Summit County as 280 feet.[2] Prof. C. L. Herrick in describing the rocks of the Cuyahoga Valley stated that "about 350 feet will include all of the Waverly which has an equivalent represented in central Ohio."[3] As we have seen above if the upper part of the Cuyahoga terrane be measured on Yellow Creek, then its thickness varies from 285 to 310 feet. The thickness of the Berea grit at Brandywine Falls, on Turners Creek near Bedford and on Chippewa Creek near Brecksville is about 40 feet and the Bedford formation near Bedford about 75 feet, the sum of which would indicate that in some parts of the Cuyahoga Valley the thickness of the Waverly series is greater than from 400 to 425 feet.

Section of Mud Brook.—About two and one-fourth miles southeast of Botzum, Mud Brook enters the Cuyahoga River from the east, about three-eighths of a mile below Crammer, formerly known as Old Portage. This brook was followed in July, 1907, by an assistant, Mr. Wm. C. Morse, who made the following report: From the mouth upward the older rocks for a long distance are concealed by alluvial and glacial deposits; but in the upper portion the Paleozoic rocks are shown. The section was barometric and subject to some error as the barometer was not reading as accurately as might be desired.

Section of Mud Brook.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Sharon conglomerate.* Top of the exposure at Puritan Mills and Iron Bridge, where there is a fall in the brook over the conglomerate. Fifteen to twenty feet of the conglomerate is here shown in a massive wall on the southern bank of the valley. The upper part of the outcrop is a dense conglomerate; but the lower portion is a coarse, gray sandstone, containing only a few pebbles	30	225
2.	*Royalton formation.* The contact between the Sharon and Royalton is clearly shown at the turbine chute. The upper portion of the Royalton consists of blue, argillaceous shales, with thin layers of sandstone and limestone. The greater part of the interval is covered by drift deposits of blue clay and gravel; but when exposed the older rocks consist of blue, arenaceous and argillaceous shales, alternating with thin layers of blue sandstone and limestone. In the basal part of this zone, which occurs about one-fourth mile above the first highway bridge below the Iron Bridge, is poorly exposed 7 to 8 feet of sandstone and blue shale. At the		

[1]Ibid., p. 184.
[2]Ibid., "Section of the Rocks of Summit County," opposite p. 222.
[3]Bull. Denison Univ., Vol. IV, 1888, p. 103.

No.		Thickness. Feet.	Total thickness. Feet.
	top is about 2 feet of sandstone, above which is till. The blue shale forms the bed of the brook, and in it just below the sandstone, is a very fossiliferous zone in which *Spirifer* and other Brachiopods, Trilobites, Bryozoa and Crinoid stems were collected	55+	195
1.	Covered to level of Cuyahoga River. Opposite the highway bridge mentioned above, which is the second one in ascending the brook, is blue clay, and high up on the banks of the highway blue clay and gravel imperfectly stratified occur. Farther down the stream are large deposits of drift sand and gravel, with some blue clay on its banks. About a mile above its mouth is an alluvial cone, from 90 to 100 yards across at its base, with about the same length, and its greatest thickness about 10 feet. It occurs at the mouth of a small gully where the steep bank of drift has been washed away. At this locality the drift consists mainly of sand, which is imperfectly stratified. Another, and considerably smaller, alluvial cone occurs farther down the brook	140	140

The total thickness of 225 feet for the above section appears to be fairly accurate, since the topographic map gives 220 feet or more as the difference in altitude between the level of Cuyahoga River and Mud Brook at the Iron Bridge.

Section in the Cuyahoga Gorge.—As is well known the Cuyahoga River at Cuyahoga Falls has cut a deep and narrow channel in the Sharon conglomerate. This gorge extends for more than two miles down the river, gradually widening as the Sharon conglomerate and Cuyahoga sandstones recede from its immediate banks and ends when the soft Brecksville shales are reached.

At the lower end of the Cuyahoga gorge on the eastern or northern bank of the river is a cliff showing some 15 feet of soft, bluish-black, fissile shale. This shale is fine as weathered and has all the appearance of the Brecksville. A little below is a high bank of boulder clay with glacial deposits of sand above, and for some distance down the river the immediate high banks are composed of glacial deposits. On the opposite side of the river a little above the bank of Brecksville shale bluish-black fissile shale is shown which makes the floor of the river at this locality. On the same side a little farther up the river 2 or 3 feet of shale is exposed. At the lower end of the outcrop it is argillaceous, somewhat blackish, weathering to a rusty color like some of the Brecksville shale. At the upper end of the outcrop, which is a little higher, the shales are blue in color, coarser, and somewhat arenaceous with thin layers of blue sandstone about one-fourth of an inch in thickness. The top of this outcrop is 5 feet or so above the level of the river

and is also very near the top of the Orangeville formation. A little farther up the river, about the top of the Orangeville formation is shown at water level, where it is blue to bluish-black in color, soft and argillaceous. This outcrop, according to the barometer, is 35 feet lower than the heavy sandstone layer at the top of the cascade just above Big Falls and it is opposite conspicuous ledges of heavy sandstone on the other bank of the river. The contact, however, of the Orangeville formation and the superjacent sandstones is not clearly shown in the gorge; but is partly concealed by talus which extensively covers the banks of the lower part of the gorge. In connection with the correlation of this shale it is interesting to note that Mr. W. F. Cooper has stated that "The Berea shale [under which term he apparently included in northern Ohio about what we are calling the Orangeville formation], which extends almost to the Big Falls, is very different, both lithologically and paleontologically from the Cuyahoga shale proper."[1] It is very evident from the above quotation that Mr. Cooper referred the soft bluish-black shales at the lower end of the Cuyahoga gorge to the lower shales of the Cuyahoga terrane, which he called the Berea shale.

On the bank at a little distance from the river and between the two outcrops of Brecksville shale last described is a conspicuous ledge of sandstone. The lower part of this sandstone is mostly covered, but it apparently runs down nearly, if not quite, to the top of the Orangeville shale. From near the apparent top of the Orangeville formation the writer leveled to the top of the highest exposed layer of this sandstone zone and in each instance made the interval 52 feet. The same interval was leveled by Dr. Wilkinson, who made it 51 feet. The bank immediately above is covered; but these observations show that succeeding the Orangeville formation there is a zone composed to a considerable extent of fairly thick-bedded sandstones which reaches a thickness of nearly 50 feet. Apparently the thickness of this zone was given as 35 feet by Prof. C. L. Herrick in his section of the Cuyahoga Valley,[2] and probably was determined by following the river from the top of the Orangeville formation to the top sandstone of Big Falls, for which interval the writer had the same result. It is thought, however, that the sandstone zone extends somewhat higher than the top of Big Falls, for on the northern side thinner bedded sandstones show in the lower part of a gully about opposite the falls. Professor Herrick described the 35-foot zone of his section as composed of "Flags and shales, with *Productus newberryi*, *Allorisma cuyahoga*, *Discina newberryi*, etc."[3]

Just beneath this zone in the Cuyahoga Valley section Professor Herrick gave 10 to 15 feet of what he called the "Berea black shale;" below which was the Berea grit 45 feet in thickness. If the black shale

[1]Bull. Sci. Lab. Denison Univ., Vol. V, 1890, p. 32.
[2]Bull. Geol. Soc. America, Vol. II, 1891, p. 40.
[3]Loc. cit., p. 40.

which Professor Herrick termed the "Berea" is at the lower end of the gorge, then as already shown it is the upper portion of the Brecksville shale; but in any case he very much underestimated the interval between the Berea grit and the base of the 35-foot zone, which is probably between 115 and 130 feet instead of 10 to 15 feet as he stated.

Above the sandstone zone somewhat farther up the river and well up on the bank are exposures of bluish argillaceous and some arenaceous shales, which contain brownish-gray, somewhat calcareous concretions and in the shales a few fossils were found, mostly Bryozoa. Somewhat farther up the river is a gully and above it a small quarry has been opened in the Sharon conglomerate. Below, in the upper part of the gully, are blue shales alternating with bluish, thin-bedded sandstones. A single reading of the barometer made the interval from the base of the quarry, which is apparently not much above the base of the Sharon conglomerate, down to the top of the Orangeville formation 150 feet. Herrick's section of the Cuyahoga Valley gives this same interval as 125 feet.[1]

The rocks are well exposed on the banks of the Cuyahoga River from the lower end of the gorge up to the top of Big Falls. A section was constructed from the outcrops along this part of the river, and thence up the northern bank to the Old Maid's Kitchen and top of cliff of Sharon conglomerate.

Section of Cuyahoga River at Big Falls.

No.		Thickness. Feet.	Total thickness. Feet.
9.	*Sharon conglomerate.* Top of cliff, above Old Maid's Kitchen. This name has been applied to an immense recess in the face of the conglomerate cliff, the roof of which is 21 feet above the base. The greater part of the face of the cliff is composed of a coarse, brownish-gray (as weathered) grit, with some pebbles and occasional layers of very coarse conglomerate. For a considerable part of the exposure, the base of the conglomerate is formed of a coarse pebbly layer, and another one is shown in the roof of the "Kitchen," where the pebbles are very coarse. There is, however, no such massive layer of coarse conglomerate as occurs near the base of the formation in the gorge below High Bridge at Cuyahoga Falls. The line of contact between the Sharon conglomerate and Cuyahoga terrane is beautifully shown, and is irregular, showing that the conglomerate was deposited on an eroded surface of the shale. This character is best shown in the western half of the exposure at this locality, where the unconformability is well marked. The Old Maid's Kitchen and lower part of the Sharon conglomerate is shown in Plate LIII. The base of the lowest ledge of massive sandstone is the base of the Sharon conglomerate------	36	178

[1]Loc. cit., p. 40.

Old Maid's Kitchen near Big Falls of Cuyahoga River, showing lower part of Sharon conglomerate.

No.		Thickness. Feet.	Total thickness. Feet.
8.	*Royalton formation.* The thickness of this top zone of the Cuyahoga terrane is variable, due to the uneven surface of the superjacent conglomerate; consequently it ranges from 3 feet downward. It consists of blue to bluish-gray argillaceous shales, with some arenaceous ones and thin sandstone layers. One of the sandstone layers from 2 to 3 inches in thickness, and just about one foot below the base of the conglomerate, where the shale is thickest, is rather fossiliferous. This fauna was apparently discovered by Prof. C. L. Herrick, who made the following statement concerning it: "The few feet of shale near the top [of the Waverly] at Cuyahoga Falls, seem to extend above any of the southern horizons and mingle fossils like Spirifer biplicatus, of the Waverly, with Coal-measure types like Entolium aviculatum."[1]	3	142
7.	Mostly covered slope to top of cascade of Big Falls. In lower part of gully a few outcrops of bluish, thin-bedded sandstones and shales. It is not improbable, that the subjacent sandstone zone extends for about 15 feet into this covered interval. At the lower end of the gorge, its top appears to be about 50 feet above the top of the Orangeville formation, while the top sandstone of Big Falls is only about 35 feet higher than the shale. Dr. Newberry gave 80 feet for the interval, from the Big Falls to the base of the Sharon conglomerate,[2] and the same thickness was given by Mr. W. F. Cooper.[3] The interval from the top of the heavy sandstone, forming the cascade at the top of Big Falls, to the base of the conglomerate, was leveled by Mr. Flory, who made it 92 feet. The barometer, for the same interval, gave for one reading, a difference of 100 feet, and at another time, 95 feet. In this zone, 40 feet below the conglomerate, Professor Herrick found a fossiliferous layer,[4] from which Mr. Cooper states that "over thirty-five species have been figured, in Bulletin Vol. IV, of Denison University."[5]	89	139
6.	Heavy sandstone, which makes the cascade at the top of Big Falls. As estimated, from the bank below the falls, there is about 8 feet, nearly all of which is a compact, fine-grained, blue to light gray sandstone, which weathers to a buff color. In the midst of this zone is a layer that is harder, contains marcasite, and is probably slightly calcareous. The layers of this sandstone, which make Big Falls, vary from 6 inches to a foot in thickness, and form about the upper half of the cliff, as seen on the northern bank below the falls. Dr. George H. Girty is reported to have stated		

[1]Bull. Denison Univ., Vol. IV, p. 103.
[2]Geol. Surv. Ohio, Vol. I, p. 210.
[3]Bull. Sci. Lab. Denison Univ., Vol. V, 1890, p. 32.
[4]Ibid., Vol. IV, 1888, p. 104.
[5]Ibid., Vol. V, 1890, p. 32.

No.		Thickness. Feet.	Total thickness. Feet.
	that "The Sharpsville sandstone representing the middle portion of the Cuyahoga is probably the stratum producing the lower falls [evidently meaning Big Falls] at the village of Cuyahoga Falls."[1]	8±	50
5.	The lower part of Big Falls, and the northern bank below the falls, consist principally of bluish to bluish-gray shales and thin-bedded sandstones. Some of the shales are argillaceous, and approach an olive color. From the river level at the base of this zone and Big Falls, to the top of the sandstone forming the cascade above Big Falls, is 17 feet by level and 18 feet by barometer. Fossils occur in these rocks, perhaps most frequently in some of the shales that form the lower part of the falls, from which several species were obtained; *Chonetes* is the most common one. Mr. W. F. Cooper has mentioned two horizons below the Sharon conglomerate at this locality, from which he collected fossils. The first, he stated, "is forty feet below the carboniferous conglomerate, the second is exposed in the series of shales and freestones of which the stratum forming the Big Falls is the top. *Allorisma cuyahoga* and a species of *Chonetes* are the only species thus far obtained from that horizon."[2]	9±	42
4.	Shales and thin-bedded sandstones	4	33
3.	Hard stratum of somewhat calcareous, blue sandstone, which weathers to a rusty color. It is 11 inches in thickness, and makes the small fall below the foot bridge	1—	29
2.	Blue, arenaceous and argillaceous shales with thin sandstone layers occur directly below the above stratum. About 4 feet below the calcareous stratum is another thinner, hard sandstone, which is also apparently calcareous. About 8 feet below No. 3, are blue, rather coarse, argillaceous shales, which are fossiliferous. Blue shales, alternating with thin-bedded, blue sandstones occur 9 feet below the base of No. 3, and similar rocks apparently continue for 5 feet lower	13±	28
1.	*Brecksville shale.* At top, blue, rather thick, arenaceous shales, with thin layers of blue sandstone, one-fourth inch in thickness. Lower, it is bluish-black, fissile shale, weathering into a smooth, dark colored bank. Lowest exposure at end of gorge	15±	15

In the above section the thickness of the intervals from the base of No. 5 to the top was obtained by hand-level or tape, while the lower part is partly barometric. There is a small fold on the northern bank just below Big Falls; but it is not thought that it has affected the result very much.

[1]Science, N. S., Vol. XIII, p. 664.
[2]Bull. Sci. Lab. Denison Univ., Vol. V, p. 32.

This section makes the thickness of the interval from the top of the Orangeville formation to the base of the Sharon conglomerate 137 feet. The barometric section on the southern side of the river made this same interval, plus perhaps a few feet of the basal portion of the Sharon conglomerate, 150 feet; but this section was measured when the barometer was falling and is probably not so accurate. This interval is given a thickness of 125 feet by Prof. C. L. Herrick in his section of the "Cuyahoga Valley and Bedford" and subdivided as follows:

"Cuyahoga shale, with *Spirifer marionensis*, *Phaëthonides spinosus*, *Proëtus præcursor*, etc	50 ft.
Concretions with same fauna, shales	40 ft.
Flags and shales, with *Productus newberryi*, *Allorisma cuyahoga*, *Discina newberryi*, etc	35 ft."[1]

A gully just above the Electric Railroad bridge on the southern side of the river affords a fair section of the upper part of the Cuyahoga terrane. The upper part of the section is covered and the contact with the Sharon conglomerate is not shown; but the base of the Sharon may be found on the bank above the path a few rods farther up the river.

Section Between the Electric Railroad Bridge and Cuyahoga Falls.

No.		Thickness. Feet.	Total thickness. Feet.
10.	Base of *Sharon conglomerate*	--	--
9.	*Royalton formation* covered in upper part of gully; but shown farther up the bank to be composed principally of bluish shales and thin sandstones	18	94
8.	Soft, argillaceous shales, exposed on upper part of bank of run	7	76
7.	About the top of the concretions. The zone composed of thin, blue, laminated sandstones and shales, containing concretions. It is fossiliferous; *Conularia* and some other forms were noted	11	69
6.	Mostly covered interval, crossed by path	12±	58
5.	About 4 feet of soft, blue, argillaceous shale, containing calcarous concretions, and exposed below the path	4±	46
4.	Stratum of calcareous sandstone, from 8 to 9 inches in thickness	¾	42
3.	Argillaceous shales, containing concretions. At the base of the zone is a sandy, concretionary layer, which is somewhat fossiliferous; and the base of the concretions in this section	14¼	41¼
2.	Shales, alternating with thin sandstones; but the proportion of sandstone is greater than in the overlying zone	12	27
1.	Covered to river level	15	15

[1]Bull. Geol. Soc. America, Vol. II, p. 40.

Not many rods above the gully, which has just been described, the lower part of the Sharon conglomerate appears as a massive rock forming the upper and steep portion of the cliff which bounds the gorge. At several places the contact of the Sharon conglomerate and Cuyahoga terrane (Royalton) is fairly well shown, together with several feet of the upper part of the last named division. At one locality, commencing about 5 feet below the base of the conglomerate, is shown about 7 feet of rocks belonging in the Cuyahoga terrane. These consist mainly of rather thin, bluish shales alternating with thin, blue sandstones. The sandstone layers reach a thickness of perhaps 3 inches and there is an occasional calcareous, rusty layer a half inch or so thick. At another place the contact is well shown where the top of the Cuyahoga is a bluish, argillaceous and very soft shale. Just above, forming the base of the Sharon, is a 15-inch layer of very coarse conglomerate above which is a coarse sandstone containing some pebbles. Farther up the river this zone is composed entirely of rather coarse conglomerate. At the prominent angle in the cliff, 300 to 400 feet below the dam and ferry, the base of the Sharon is shown, below which for several feet the uppermost Cuyahoga is mostly covered with dirt. The Cuyahoga rocks as exposed on this bank, however, consist mainly of bluish to bluish-gray thin, evenly bedded arenaceous shales to thin-bedded sandstones; but there are also alternating bands of thin fissile shale which is more or less argillaceous. On the opposite or western bank of the river just below the dam probably the upper 8 feet of the Cuyahoga terrane is shown. The rocks consist apparently of bluish shales alternating with thin sandstones. This observation, however, was made on the opposite bank of the river since the exposure can be reached only by a boat, which was not available at the time of the examination. Above the dam the base of the Sharon conglomerate extends nearly or quite to the river level and forms nearly vertical cliffs on both sides about 70 feet in height. This is an admirable locality for studying the Sharon conglomerate and one famous in Ohio for its natural beauty. On the western side at the foot of the stairs the lower 17 feet of the Sharon is composed of typical conglomerate in which the pebbles are large and thick. On the opposite bank of the river the heavy conglomerate is apparently not so thick and this conglomerate zone seems to be somewhat irregular in its extent. This zone is the basal conglomerate of the Sharon member of the Pottsville formation. Above the coarse conglomerate zone the rock is mainly a coarse sandstone, with smaller pebbles than in the basal zone scattered somewhat sparingly through it and varying in abundance. The conglomerate and sandstone near the river is gray in color and more or less brownish from iron staining. Within about 8 feet of the top of the cliff, as seen from the high bridge over the river, is a coarse pebbly layer about 18 inches thick. The thickness of the Sharon conglomerate exposed in these cliffs is about 70 feet according to the

barometer. This is the same as the thickness assigned to the "Carboniferous conglomerate" by Prof. C. L. Herrick in his section of the "Cuyahoga Valley and Bedford."[1]

Akron Section. — The older rocks in the vicinity of Akron are largely covered by recent deposits of sand and gravel which in certain localities have a very considerable thickness. In the northern part of the city is a bluff in which are perhaps the best exposures of the conglomerate to be found in Akron. At the northeastern end of the bluff, to the north and below Bluff Street near the end of North Union Street, is the old Hugill quarry, now abandoned. The barometer and tape both gave 50 feet of rock exposed in this quarry, which was the greatest thickness seen in any one exposure in the city. The color on the weathered face of the quarry is either a dark or brownish-gray. The rock in the upper part of the cliff is irregular in bedding and shattered, then there is a zone of rather massive sandstone, below which is a zone of coarse, cross-bedded rock, while deeper is the very massive stone of the quarry, 17 feet in thickness. In the deepest part of the quarry is a zone of massive stone, about 6 feet thick, which is underlain by thinner bedded sandstone. The rock shown in this cliff is in general a rather coarse sandstone to grit, containing but few pebbles. Nearly one-half of the cliff is composed of very massive sandstone, while the remainder is thinner and more or less irregularly bedded, with some shale partings.

Below the quarry is an excavation by the Ohio Northern Railroad, above the canal, the base of which is 35 feet below the base of the Hugill quarry. At this locality the rock is in part a conglomerate, although the pebbles are not coarse; but in part of it are somewhat numerous thin layers of coarse conglomerate. This gives a thickness of at least 85 feet for the Sharon conglomerate in Akron. In the Fair Grounds, on the bank of the Little Cuyahoga, 70 odd feet below the conglomerate exposure on the raiload, is an outcrop of bluish shales and sandstones belonging in the Cuyahoga terrane. The following section has been constructed from the Little Cuyahoga to the top of the Hugill quarry:

Section in Northern Akron from the Little Cuyahoga to Top of Hugill Quarry.

No.		Thickness. Feet.	Total thickness. Feet.
6.	*Sharon conglomerate.* Top of Hugill quarry. Thinner bedded and shattered sandstone in upper part. Massive sandstone. Cross-bedded zone. Thinner bedded sandstone. The above details are shown most clearly near the eastern end of the quarry, while at the western end the high cliff is nearly all massive sandstone, except the shattered layers on top	27	165

[1]Ibid., Vol. II, p. 40.

No.		Thickness. Feet.	Total thickness. Feet.
5.	Very massive sandstone, forming most valuable part of quarry	17+	138
4.	Lower massive ledge. Thinner layers at base, which is the bottom of the Hugill quarry	6—	121—
3.	Mostly covered; but lower part exposed above the canal by railroad, showing a conglomerate zone. In general, the pebbles are not coarse; but in part of the exposure are numerous thin layers of coarse conglomerate. This is the lowest outcrop of the conglomerate seen and shows that its thickness is at least 85 feet	35	115
2.	Covered interval; 92 feet by barometer and 72 as leveled	72	80
1.	*Cuyahoga terrane.* On the bank and in the bed of the Little Cuyahoga, 8± feet of bluish shales and sandstones containing concretions, are shown. Some fossils were noted	8 ±	8

The Sharon conglomerate is reported as underlying Buchtel College, which is probably true, but no exposures were visible at the time the campus was visited. In particular the engine house is said to be on rock foundation.

In the southern part of the city, Wolfe ledge and Wilhelm's quarry give some idea of the appearance of the conglomerate. The quarry is at the southern end of the ledge on East South Street. The rock is a light-gray coarse sandstone to grit, composed of rather coarse quartz grains with occasional quartz pebbles. It is loosely cemented, has numerous small brownish spots and shows fine examples of cross-bedding. On old exposures it is weathered to a very dark-gray color. The rock is quarried mainly for construction blocks.

Section of Wilhelm's Quarry.

No.		Thickness. Feet.	Total thickness. Feet.
2.	Shattered layers near the top of the quarry	$5\frac{1}{2}$	$19\frac{1}{2}$
1.	Light-gray, coarse, massive sandstone, containing some pebbles and numerous brown spots. There is also much cross-bedding. Base of quarry	14	14

In the old part of the quarry at the northern end of the ledge 28 feet of the coarse, massive sandstone is shown, which has weathered on the faces to a dark-gray color. The upper part of the cliff shows marked and coarse cross-bedding.

Well Sections in the Akron-Barberton District.—A well drilled some years ago in the Sixth Ward of Akron by the Akron Sewer-Pipe Works was described by Dr. Orton[1] and its record may be represented diagrammatically as follows:

[1]Geol. Surv. Ohio, Vol. VI, 1888, pp. 357, 358.

Akron Well Section.

Depth	Thickness	Formation
0′	50′	Drift
50′	40′	Sharon conglomerate
90′	170′	Cuyahoga blue shale
260′	3′	Berea grit
263′	1862′	Bedford shale Cleveland, Chagrin and Huron shales, which equal the Ohio shale
2125′	335′	Devonian limestones Monroe formation An appearance of sand in the deepest drillings
2460′		

At Kenmore is the plant of the Colonial Salt Company, and through the kindness of Mr. Elmer Turner, vice-president and treasurer of the company, samples were saved of the drillings from a well put down in 1902. The drillings were thoroughly washed and dried; and later samples of them were packed by Dr. Clinton R. Stauffer and sent to the writer for study. Unfortunately, in some parts of the well, samples were not saved sufficiently close together to enable one to indicate the line of division between certain formations; still it is altogether an interesting and valuable record. The label on the first sample reads "15 to 42 feet," which is the plan followed in marking all the samples from this well; consequently it is impossible to state from what part of each zone the sample was taken.

Section of the Colonial Salt Company's Well at Kenmore.

No.	Description of sample.	Thickness of zone. Feet.	Total depth. Feet.
	First 15 feet probably drift. No sample furnished	15	15
1.	*Sharon conglomerate.* Sand, white quartz and other pebbles	27	42
2.	*Cuyahoga terrane.* Gray to bluish, argillaceous to finely arenaceous chips, which are rather coarse	14	56
3.	Rather fine-grained, gray sandstone, composed largely of fine, white quartz grains. No effervescence in HCl	14	70
4.	Mainly bluish-gray, argillaceous shale	12	82
5.	Mainly gray to bluish-gray, argillaceous shales in fine chips. Some chips are coarser and arenaceous	158	240
6.	Bluish, rather soft, argillaceous shale	25	265

No.	Description of sample.	Thickness of zone. Feet.	Total depth. Feet.
7.	Mainly blackish or bluish, argillaceous shale, with brownish streak. Some gray, finely arenaceous chips, which are perhaps from the Berea grit	75	340
8.	*Berea grit.* Mainly chips of gray, fine-grained, quartz sand. A few chips of bluish, argillaceous shale	20	360
9.	*Bedford formation.* Mainly bluish to bluish-gray, argillaceous or somewhat arenaceous chips. Certain ones are slightly calcareous	100	460
10.	Gray to bluish-gray, coarse chips, apparently from the *Chagrin formation.* No black chips representing the Cleveland shale were saved	140	600
11.	Large chips of blue, argillaceous shale	100	700
12.	Bluish to blackish, argillaceous shale, soapy to the touch with white to somewhat brownish streak	200	900
13.	Bluish, argillaceous shale, soapy to the touch, with white to somewhat brownish streak	65	965
14.	Black shale with brown streak. Most of the chips are rather fine. *Huron shale*; but perhaps not all of the zone is so black a shale	455	1420
15.	Large chips of black or blackish shale, with brownish streak; but an occasional chip with whitish streak	100	1520
16.	Blue, argillaceous shale, very soft and somewhat calcareous	275	1795
17.	Bluish-black to blackish shale; streak mostly white, but occasionally slightly brownish	255	2050
18.	*Devonian limestone.* Gray chips, effervescing strongly in cold HCl. Contains a considerable percentage of black shale chips, probably from higher in the well	80	2130
19.	Mainly gray to slightly brownish-gray limestone chips, effervescing strongly in cold HCl. Some blackish shale	10	2140
20.	Light-gray chips, which effervesce very strongly in cold HCl	10	2150
21.	Light gray to drab, compact limestone chips, which effervesce readily in cold HCl	160	2310
22.	Chips much the same as above sample, slightly more brownish, but effervescing rather strongly after a little time in cold HCl	80	2390
23.	*Sylvania sandstone* (?). Sample composed mainly of rounded grains of white quartz sand. A few grains of limestone, effervescing in cold HCl	8	2398
24.	Chips very fine, part of them effervescing readily in cold HCl, and part are fine quartz grains	10	2408
25.	Chips very fine, brownish-gray, and effervesce strongly in cold HCl. A few chips of black, argillaceous shale from above	34	2442
26.	Mainly fine, brownish-gray chips, which effervesce slowly in cold HCl. A few large chips of bluish-gray shale	10	2452
27.	Fine, light-gray chips, which effervesce very slowly in cold HCl	23	2475
28.	Fine chips, mostly darker gray than above sample, which effervesce strongly in cold HCl. An occasional larger chip of dark gray limestone	75	2550

No.	Description of sample.	Thickness of zone, Feet.	Total depth. Feet.
29.	Brownish-gray, fine chips, effervescing strongly in cold HCl	42	2592
30.	Rock salt } Dirty white color	58	2650
31.	Rock salt } Dirty white color	50	2700
32.	Very fine chips, effervescing somewhat strongly in cold HCl. Some salt in the sample	52	2752
33.	A sample marked 2752 feet, consists mainly of chips of clear white halite (rock salt). Bottom of well.		

The samples from the above well apparently indicate that the base of the Sharon conglomerate was reached at a depth of 42 feet and the base of the Cuyahoga terrane at a depth of 340 feet, giving the Cuyahoga a thickness of 298 feet. This is 128 feet greater than in the well at Akron where Dr. Orton reported the thickness of the Cuyahoga blue shale as 170 feet[1] but it agrees fairly well with the writer's estimates of its thickness in the Cuyahoga Valley. As has already been stated in this bulletin in the Yellow Creek region the thickness of the Cuyahoga terrane apparently lies between 285 and 310 feet and in the Cuyahoga Gorge between 250 and about 270 feet. The Cleveland shale, Chagrin formation and Huron shales of northern Ohio are considered the equivalent of the Ohio shale of central and southern Ohio, and in the Kenmore well the thickness of this shale together with that of the overlying Bedford formation is 1,690 feet, or 172 feet less than that of the same formations in the Akron well, which Dr. Orton reported as 1,862 feet in thickness. The sandstone reached at a depth of 2,390 feet or 340 feet below the top of the Devonian limestone apparently corresponds with the first sandstone reached in the Cleveland wells which has been provisionally correlated with the Sylvania sandstone. In the Cleveland wells it will be remembered that this sandstone was reached at a depth of 310 feet in the Newburg, 364 feet in the Jewett farm, 372 feet in the Euclid, 375 feet in the Second and Central avenues and 390 feet in the Madison Avenue below the top of the Devonian limestone; while in the Akron well Dr. Orton reported the appearance of sand at its bottom, at a depth of 335 feet below the top of the Devonian limestone. Its thickness, however, has decreased markedly from that in the Cleveland wells. There is clearly 8 feet of the sandstone in the Kenmore well to which perhaps part of the following 10-foot zone ought to be added, making not more than 12 to 14 feet of sandstone. In the Newburg well 40 feet of sandstone was reported, in the Madison Avenue 33 feet of white sandstone followed by 11 feet of limestone, below which was again 16 feet of white sandstone, making a total of 60 feet of sandstone and sandy strata, while in the well at the corner of Second and Central avenues there is 55 feet of glassy quartz sandstone followed by 40 feet which is composed partly of sand but to a greater extent of limestone, making a total of 95 feet of sandstone and sandy strata. The interval from the

[1]Ibid., p. 357.

top of the Devonian limestone to the top of the salt in the Kenmore well is 542 feet, which is less than in the Cleveland wells. In the Newburg well this interval is 640 feet, in well No. 4 of the United Salt Company, at the foot of Madison Avenue, 775 feet and in the one at the corner of Second and Central avenues 792 feet. The interval from the base of the 8-foot sandstone zone in the Kenmore well to the top of the salt is 194 feet; while 108 feet of rock salt apparently occurs commencing at a depth of 2,592 feet and, after an interval of 52 feet of limestone, rock salt is again apparently reached at a depth of 2,752 feet at the bottom of the well. In the Newburg well 164 feet of rock salt with some thin bands of shale was reached at a depth of 1,990 feet; 96 feet deeper 50 feet of rock salt was passed through; at an additional depth of 100 feet another zone of rock salt 20 feet thick was penetrated and finally 50 feet deeper 5 feet more of rock salt occurred, making a total thickness of about 239 feet of rock salt in this well. In well No. 4 of the United Salt Company at the foot of Madison Avenue, rock salt was reached at a depth of 1,765 feet and five layers give a total thickness of 170 feet; while well No. 5 of the same company, located in the vicinity of the one noted above, likewise passed through five strata of rock salt with a total thickness of 145 feet. Rock salt in the well at the corner of Second and Central avenues was reached at a depth of 1,822 feet and four strata were reported with a total thickness of 97 feet.

A condensed diagrammatic section of the Kenmore well showing the general age of the formations, so far as it can be determined from the samples, is given below:

Condensed Record of Kenmore Well.

0′		Mouth of well	
	15′	Drift (?)	
15′			
	27′	Sharon conglomerate	
42′			
	298′	Cuyahoga terrane	
340′			
	20′	Berea grit	
360′			
	1690′	Bedford formation and Ohio shale	
2050′			
	340′	Devonian and Lucas limestones	Probably represents the Monroe formation or Salina beds of New York
2390′			
	8′	Sylvania sandstone	
2398′			
	354′		
2752′		Bottom of well	

There are several wells in Barberton and the Columbia Chemical Company has drilled eleven. Well No. 1 of this company was drilled in 1899, a partial record of which was furnished the writer by Mr. H. A. Galt, the General Manager, while the complete log has been published by Professor Bownocker.[1] A condensed record in diagrammatic form of this well is given below:

Condensed Record of Barberton Well.

Depth	Thickness	Stratum	
0′		Mouth of well	
	90′	Drift	
90′			
	45′	"Soft, black slate"	
135′			
	15′	"Soft, black sand"	
150′			
	310′	Cuyahoga terrane	
460′			
	10′	Berea grit	
470′			
	1710′	Bedford formation and Ohio shale	
2180′			
	320′	Devonian and Lucas limestones	
2500′			
	30′	Brown, very hard sandstone. Sylvania	
2530′			
	244′	Limestone	
2774′			
	30′	1st Rock salt	
2804′			
	16′	Limestone	
2820′			
	5′	2d Rock salt	Probably represents the Monroe formation or Salina beds of New York
2825′			
	5′	Limestone	
2830′			
	69′	3d Rock salt. This stratum used for soda ash	
2899′			
	49′	Limestone	
2948′			
	14′	4th Rock salt	
2962′			
	44′	Limestone	
3006′		Bottom of well	

[1]Am. Geologist, Vol. XXXV, 1905, pp. 374, 375.

The lowest zone in Professor Bownocker's record was given as "lime * * * 107 ft;"[1] but in the record furnished by Mr. Galt it consists of an upper limestone of 49 feet separated by 14 feet of rock salt from the 44-foot lower limestone as shown in the above record.

Barberton Well No. 11.—Mr. H. A. Galt kindly furnished the writer with a partial set of drillings and the driller's log of well No. 11, which is as follows.

Sand from surface,	78 ft., 10-inch drive pipe	from	0 ft.	to	78 ft
Black shale,	12 ", water in the upper 5 ft	"	78 "	"	90 "
White shale,	5 ", more water	"	90 "	"	95 "
Black slate,	171 "	"	95 "	"	266 "
266 feet of 8⅝-inch casing, which shut off all fresh water.					
White slate,	204 ft.	"	266 "	"	470 "
Black slate,	30 "	"	470 "	"	500 "
White slate,	550 "	"	500 "	"	1050 "
Black slate,	200 "	"	1050 "	"	1250 "
White slate,	150 "	"	1250 "	"	1400 "
Black slate,	50 "	"	1400 "	"	1450 "
White slate,	50 "	"	1450 "	"	1500 "
Black slate,	375 "	"	1500 "	"	1875 "
White slate,	150 "	"	1875 "	"	2025 "
Brown slate,	155 "	"	2025 "	"	2180 "
Gray lime,	305 "	"	2180 "	"	2485 "
At 2180 is the top of the Niagara lime = Devonian limestone.					
Gray lime,	50 "	"	2485 "	"	2535 "
2485 feet is at top of bittern water.					
Brown lime,	204 "	"	2535 "	"	2739 "
Put in 2535 ft. of 6-in. casing, with packer on bottom.					
1st salt,	32 "	"	2739 "	"	2771 "
Brown lime,	10 "	"	2771 "	"	2781 "
2d salt,	5 "	"	2781 "	"	2786 "
Brown lime,	5 "	"	2786 "	"	2791 "
3rd salt,	82 "	"	2791 "	"	2873 "
White slate,	62 "	"	2873 "	"	2935 "
4th salt,	10 "	"	2935 "	"	2945 "
Brown lime,	15 "	"	2945 "	"	2960 "
5th salt,	10 "	"	2960 "	"	2970 "
Brown lime,	30 "	"	2970 "	"	3000 "
6th salt,	30 "	"	3000 "	"	3030 "
Brown lime,	10 "	"	3030 "	"	3040 "
7th salt,	25 "	"	3040 "	"	3065 "
Brown lime,	7 "	"	3065 "	"	3072 "
White slate,	26 "	"	3072 "	"	3098 "
Gray sand,	10 "	"	3098 "	"	3108 "
White slate,	17 "	"	3108 "	"	3125 "
Brown lime,	75 "	"	3125 "	"	3200 "
8th salt,	8 "	"	3200 "	"	3208 "

[1] Ibid., p. 375.

Brown lime,	92 ft.	from 3208 ft.	to 3300 ft.
White slate,	12 "	" 3300 "	" 3312 "
Brown lime,	38 "	" 3312 "	" 3350 "
White lime,	10 "	" 3350 "	" 3360 "
Brown lime,	65 "	" 3360 "	" 3425 "

Total depth of well, 3425 feet.

Eleven samples of the drillings from this well were sent the writer by Mr. Galt, upon which the depths were marked as given below:

No.	Description.	Depth.
1.	Soft, argillaceous shale, which is of drab or dark gray to blackish color. An occasional sandstone chip	78 to 400 ft.
2.	Mainly dark gray to blackish, argillaceous shale. Some is drab or light-gray in color	400 " 875 "
3.	Black or dark gray, argillaceous shale, the black with a brown streak	875 " 1200 "
4.	Black, argillaceous shale with brown streak	1200 " 1475 "
5.	Light-gray shale with white streak, rather tough	1475 " 1800 "
6.	Rather tough, black shale, with brown streak	1800 " 2180 "
7.	*Top of Devonian limestone.* Light-gray chips, which effervesce strongly in cold dilute HCl. Some chert chips	2180 " 2300 "
8.	Light-gray limestone, which effervesces moderately in cold HCl. Some of the chips are rather large	2300 " 2410 "
9.	Fine, brownish chips, which effervesce strongly in cold HCl. "Showing of oil and gas."	2410 " 2535 "
10.	Rather bluish-gray, fine chips, which effervesce slowly in cold HCl, leaving large residue. Some crystals of selenite. Top of first salt at 2739 feet	2535 " 2739 "
11.	Brownish-gray, fine chips, which after a little effervesce strongly in cold HCl. Sample from a depth of 3425 feet, the bottom of the well	3425 "

It is interesting to note that according to the reports the top of the Devonian limestone was reached in both Nos. 1 and 11 of the Barberton wells at a depth of 2,180 feet. In well No. 1 at a depth of 2,774 feet, 594 feet below the top of the Devonian limestone, the first rock salt was reached, while in well No. 11 it was only 559 feet or at a total depth of 2,739 feet. The same interval in the Kenmore well is 542 feet. In well No. 1 four layers of salt were penetrated with a total thickness of 118 feet; in No. 11 the first four layers have a total thickness of 129 feet below which four more layers were penetrated with a thickness of 73 feet, making a total thickness of 202 feet of salt in this well. The two upper layers of salt in the Kenmore well have a combined thickness of 108 feet.

Well No. 11 is the most interesting in some respects of any of these wells on account of its depth. In it rock salt was first reached at a depth of 2,739 feet while the bottom of salt No. 8, and the lowest, was reached at 3,208 feet, 1,028 feet below the top of the Devonian limestone, giving a total thickness of 469 feet for the strata in which the salt occurs, of which 202 feet or nearly one-half the thickness is rock salt. The well was drilled to a depth of 3,425 feet, 217 feet below the bottom of the lowest salt bed, apparently without reaching the bottom of the Monroe formation. If this be correct, then the thickness of the Devonian limestones and Monroe formation in the Barberton region is greater than 1,245 feet.

CHAPTER II

THE CHAGRIN VALLEY

The first river east of the Cuyahoga is the Chagrin which rises in the northern central part of Geauga County and flows southwesterly until near the center of the township of Chagrin Falls in the eastern part of Cuyahoga County, where it turns northerly and flows across the extreme eastern part of Cuyahoga County and western part of Lake County, emptying into Lake Erie. Below Chagrin Falls it is frequently bounded by steep hills on one or both sides, with occasional precipitous cliffs. This picturesque valley, which is attractive to the admirer of nature as well as to the geologist, is easily reached from Cleveland by means of three electric lines and two railways. Near the northern end of the valley is the village of Willoughby, which is readily reached by the Lake Shore & Michigan Southern and New York, Chicago & St. Louis railroads and the Cleveland, Painesville & Eastern electric line. Gates Mill near the middle of its northern course is on the Cleveland & Eastern division of the Eastern Ohio Traction Company, and this attractive locality is well known as a suburban and summer resort for Cleveland people. Finally, Chagrin Falls and the southern part of the river gorge is on the Chagrin Falls division of the Eastern Ohio Traction Company in a picturesque region for a summer outing and one of decided attractiveness for the geologist.

The Chagrin Bluffs Above Willoughby.—On the eastern side of the Chagrin River, about one and one-half miles above Willoughby, opposite Mr. Bunnell's farm and just below the iron highway bridge, which is the first one above the village, is a bank of the Chagrin formation, perhaps nearly 100 feet in height. The lower part is composed of bluish, argillaceous shales with numerous grayish, calcareous layers which weather on the surface to a rusty brown color. These layers vary from about one-half inch to rather more than an inch in thickness and tend to form somewhat concretionary lenses. A rather careful search for fossils was made in the lower rocks of this cliff; but without success. On the western side of the river, commencing a short distance above the highway bridge, is another high cliff of the Chagrin formation. From this cliff one piece of a calcareous layer was found that contained several poorly preserved specimens of *Liorhynchus mesicostale* Hall (?) together with others of what Lesquereux considered

as probably marine algæ which he described under the name of *Physophycus bilobatus* from cliffs bordering Lake Erie, near Cleveland.[1] These specimens do not agree exactly with the figures of this species. The ends are not rounded in quite the same fashion as the figures and the divided portion varies somewhat in shape. The specimens occur on argillaceous, ironstone concretions in a similar manner to those described by Lesquereux and it appears advisable to refer them with a query to this species rather than to describe such problematical forms as new. An occasional specimen of apparently the same form was found in the concretions imbedded in the shales below the bridge. These rocks weather into smooth cliffs and apparently belong stratigraphically in the lower division of the Erie shales as they were described and divided by Dr. Newberry in the vicinity of Cleveland.[2] The upper portion of the cliffs as seen from the river apparently contain thin-bedded layers of sandstone alternating with shales and probably belong in the lower part of Newberry's upper division of the Erie shale which he described as composed of soft green, gray and blue shale with thin bands of sandstone.

High banks occur occasionally as the Chagrin River is ascended and about four miles above Willoughby is a magnificent cliff on the eastern side of the river. This cliff is about one mile below Pleasant Valley, opposite the house of John Dodd, and is 100 feet or more in height. The rock weathers to a comparatively smooth surface and at a distance looks like a clay bank. A view of this bank, photographed at some distance, is shown in Plate XVI, A, which gives an excellent idea of these smooth, steep cliffs of Chagrin shale, somewhat furrowed by descending rills.

These banks along the Chagrin River are the typical locality for the Chagrin formation as the following quotation from the writer's original description shows:

"The name *Chagrin formation* is, therefore, proposed for this mass of argillaceous and arenaceous shales and calcareous layers on account of the excellent exposures on the banks of this river extending from Willoughby to the south of Pleasant Valley. With perhaps the exception of the cliffs on the shore of Lake Erie, there are probably no finer outcrops of the formation to be found than those forming the steep banks of the Chagrin River. One and one-half miles south of Willoughby is a cliff nearly a hundred feet high, and a magnificent one more than a hundred feet high occurs a mile below Pleasant Valley, about four miles up the river southeast of Willoughby."[3]

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[1]Proc. U. S. Nat. Mus., Vol. XIII, 1890, p. 9.

[2]Geol. Surv. Ohio, Vol. I, 1873, p. 163.

[3]Jour. Geology, Vol. XI, 1903, pp. 533, 534. Also see Geol. Surv. Ohio, 4th ser., Bull. No. 7, 1905, pp. 21, 22.

On the bank of the Chagrin River at Pleasant Valley the bluish soft shale of the Chagrin formation is well shown and there is also a big fill of glacial clay and sand. A little above Pleasant Valley is a fairly high cliff of the Chagrin formation and then lower banks prevail until near Gates Mill. At this latter locality, however, it is only the lower part of the cliff that belongs in the Chagrin formation.

Wilson Mills Sections.—Three and one-half miles above Pleasant Valley is the small village of Wilson Mills, formerly called Macksville, and for some distance below and above it there is a valley of some width limited in the main by hills of more gradual ascent. About opposite the village the western bank of the Chagrin River is rather abrupt and perhaps about 25 feet of Chagrin shale is shown. On the same side of the river, and a little below this bank, Sherman Creek enters from the west, one fork of which rises near the center of the township to the west of the hamlet called Mayfield Center. The lowest outcrops in this stream occur a few rods above the river road and consist of blue argillaceous shale which weathers to an olive color with layers of blue, thin-bedded sandstone from 1 inch to 3 inches in thickness. From 12 to 13 feet of rocks, which belong in the Chagrin formation, are exposed at this point. The base of this outcrop is barometrically 25 feet above the level of the Chagrin River and 180 feet below the top of the formation. On ascending the stream, 95 feet higher than the base of the outcrop just described, a layer of blue shaly sandstone 1 foot 2 to 1 foot 3 inches in thickness, which weathers to a rusty color, is reached. Still 85 feet higher or 180 feet above the lowest outcrop, in a small gully on the southern side of the stream, is the contact of the Chagrin formation and Cleveland shale. There is a sharp transition from the bluish-gray shales of the Chagrin, which in the upper part are rather sandy with thin layers of blue sandstone, to the black, bituminous shales of the Cleveland. A layer of blue sandstone about 1 inch thick occurs in the Chagrin only 3⅓ feet below the line of contact. The bank is a difficult one to climb; but apparently more than 20 feet of Cleveland shale is shown on it, which agrees with Dr. Newberry's statement that "In a ravine just below Macksville, the black, Cleveland shale is exposed * * * apparently, but 23 feet in thickness."[1] A little farther up the stream, however, on its northern bank the limits of the Cleveland shale are better defined where both the barometer and hand-level made its thickness 30 feet. Here there is apparently a rather strong dip down stream to the east. The section of the northern bank of the stream at this locality is as follows:

[1]Geol. Surv. Ohio Vol. I, pp. 199, 200.

Section on Bank of Sherman Creek.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
7.	Sandstone of *Bedford*	--	--	--	--
6.	Shale	--	--	--	--
5.	Blue sandstone	--	5	39—	--
4.	Mostly covered zone, but a little bluish shale is shown at the top; probably all in the Bedford	3	8	38	6
3.	*Cleveland shale.* Black, tough and bituminous, 30 feet clearly shown on steep bank	30	--	34	10
2.	*Chagrin formation.* Soft, blue shales, which form the highest zone of this formation	2	10	4	10
1.	Blue shales, alternating with thin blue sandstones, about 1 inch thick, to the stream level	2±	--	2	--

The Cleveland shale is finely shown on the banks of the stream, above the section just described, and in the lower part of the cascade, above which is shown the lower portion of the Euclid member of the Bedford formation. The sandstone forms the floor of the stream under the highway bridge opposite the house of F. and B. Worts on the road running north from Mayfield Center, which is apparently its highest outcrop on this stream. The Cleveland shale was leveled from its base in the stream to its top in the cascade which gave a thickness of 25 feet 8 inches. This measurement is probably a little greater than the actual thickness, the error due to the dip down stream. The following section was measured in the stream from the base of the Cleveland shale to the top of the sandstone under the highway bridge:

Section on Sherman Creek.

No.		Thickness. Ft.	Thickness. In.	Total Thickness. Ft.	Total Thickness. In.
6.	*Euclid member of Bedford formation.* The top of the sandstone forms the floor of the stream under the highway bridge. Sandstone alternating with shale. The sandstones of this zone are thicker than those in the zones below	8	9	36	4
5.	Shale	--	4	27	7
4.	Sandstone	--	1	27	3
3.	Bluish-gray shale	1	3	27	2
2.	Compact sandstone of bluish-gray color at the base of which is the contact of the Bedford formation and Cleveland shale	--	3	25	11
1.	*Cleveland shale.* Black, tough, bituminous shale. The contact with the Chagrin formation is clearly shown	25	8	25	8

The rocks exposed on this stream may be represented by the following diagrammatic section in which below the Cleveland shale the outcrops are not continuous and there are various covered zones:

Section of Sherman Creek.

$245\frac{2}{3}'$		Top of section under highway bridge
	10′ 8″	Lower part of Euclid member of Bedford formation Sandstones with bluish-gray shale
235′		
	30′	Cleveland shale, black and bituminous
205′		
	180′	Chagrin formation. Blue, argillaceous shales, with thin sandstones; but part of interval covered About 13 feet of shales shown at base of zone
25′		
	25′	Covered to level of Chagrin River
0′		

To the southeast of Wilson Mills is a glen known as Fletcher's Gully, the stream from which crosses the highway about 40 rods south of the village. The glen is back of the house of Mrs. M. M. Covert on the river road and on the S. E. Higgins farm. It is a rather romantic locality with walls in places 175 feet or more in height and was mentioned in Dr. Newberry's report on Cuyahoga County.[1] The gully was examiend somewhat hastily and the following section has been prepared which extends to the upper road.

Section of Fletcher's Gully.

No.		Thickness. Feet.	Total thickness. Feet.
6.	*Sunbury shale.* On the wash bank, below the highway, a few rods northeast of the farm-house of Mr. S. Quigley, are broken and weathered bits of black shale, evidently from the Sunbury	--	--
5.	*Berea formation.* The top of the formation is shown in the stream at the top of the upper cascade at the old dam, just above the site of the old sawmill. A few rods below the house of S. Quigley is an old quarry on the northern bank of the stream, in the upper layers of the formation, which have weathered to a rusty color. Below this quarry is the beginning of the gorge where the stream has cut through the greater part of the Berea sandstone and falls over the lower, thick layers. Some of the Berea above the coarse, basal		

[1]Ibid., p. 200.

No.		Thickness. Feet.	Total thickness. Feet.
	layers, as shown in the cliffs, is thin-bedded, not valuable for quarrying and there is also some cross-bedding. The top of the cliff on the northern bank, above the falls, is rough and pitted like the general appearance of the top layer of the Berea. The lowest, heavy layer in the falls is 5 feet 9 inches in thickness, composed of coarse, quartz grains and shows numerous brownish spots. These lower, heavy layers are apparently of good quality and have been quarried to slight extent in the creek at the fall. From the base of the lowest, massive layer to the top of the highest one on the cliff above the fall, is 55 feet by the barometer, and 54 feet by hand-level. There is absolutely no question but that all of this interval ought to be put in the Berea formation, which gives it a greater thickness by 14 feet than in Dean's Gully, only 1½ miles farther south. Below the massive, coarse-grained layer is a 6-foot zone, varying from arenaceous shales to thin layers of sandstone, the thickest one about 3 inches; but most of them not more than 2 inches or less in thickness. The thin sandstones in the upper part of this zone show numerous ripple-marks, and are composed largely of fine, quartz grains. At the base is a layer 1 foot thick, of bluish-gray, fairly fine-grained sandstone; but apparently a considerable percentage of the rock is composed of fine, quartz sand. The lowest 1-foot sandstone greatly resembles, lithologically, the lowest sandstones referred to the Berea formation in Griswold Hollow and Big Creek, on the Stone farm to the north of Chardon, which are described farther on in this bulletin. It is believed to be better to include this lower 7-foot zone in the Berea rather than in the Bedford formation, which will give the Berea a thickness of 61 feet in this section. It is thought that Dr. Newberry referred this shaly zone to the Berea, for he stated that in Fletcher's Gully "the Berea has a thickness of about 60 feet, the upper portion thin-bedded as usual, and the whole resting upon gray shale."[1]	61	369

[Since this gully was studied and the above account written, additional examination of the sections in Griswold Hollow and Big Creek, on the Stone farm, has convinced the writer that the fine-grained sandstones which at first were considered the basal part of the Berea, really belong in the Bedford formation. It is quite probable that part, if not all, of the 7-foot zone referred to the base of the Berea in this section belongs in the Bedford formation. If this be correct, then the thickness of the Berea will be reduced to 54 feet and that of the Bedford increased to 112 feet.]

[1]Ibid., p. 200.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Bedford formation.* The 1-foot sandstone described above is about at the base of the exposure in the fall, and below in the stream are immense blocks of loose Berea grit. The rocks are mostly concealed, but shales and thin sandstones of the Bedford are shown at some distance down the stream, and the base of the outcrop is barometrically 58 feet lower than the 1-foot sandstone considered the base of the Berea formation. The rocks are then mainly concealed for 47 feet, when lower black shale occurs in place. Above the black shale, on the sloping bank, are loose, gray shales and sandstones of the Bedford formation. It will be seen that the barometer made the thickness of the interval from the base of the Berea to the top of the exposed black shale 105 feet; but it was not shown that all of this interval belongs in the Bedford formation since perhaps its lower part includes the upper portion of the Cleveland shale	105	308
3.	*Cleveland shale.* Only 8 feet of black, bituminous shale is shown on the northern side of the bank, but undoubtedly more of the shale is concealed. When in the field it was thought that this outcrop of shale was in the upper part of the Cleveland; but the thickness of the interval from its top to the base of the Berea (105 feet) makes this opinion doubtful, since in Dean's Gully, one and one-half miles to the south, the Bedford formation is but 93 feet in thickness	8+	203
2.	*Chagrin formation.* Below the outcrop of Cleveland shale the bed rocks are concealed for a considerable distance by the rocks and dirt, which have slid down the banks. By the barometer, 110 feet lower than the base of the black shale outcrop is the base of the lowest outcrop of the Chagrin shale. This outcrop is at the lower end of the gorge, where about 10 feet of argillaceous, bluish shale, with rusty concretions, arranged in layer-like fashion, occurs in the northern bank of the stream. On the same bank, above the outcrop of Chagrin shale, and farther up the stream are clay and drift deposits	110	195
1.	Alluvial deposits to the Chagrin River, near the mouth of the stream from Fletcher's Gully	85	85

In the above section perhaps the intervals determined entirely by the barometer are slightly too great for it gives a difference in elevation of 284 feet between the lowest outcrop of the Chagrin formation and the top of the Berea grit; while in descending the glen the barometer with one-half hour's difference between the two readings gave only 250 feet for the same interval.

Gates Mill Sections.—About two and one-half miles above

Wilson Mills is the attractive village of Gates Mill, which in recent years has become the summer home of a number of Cleveland families. The village proper is situated in the valley hard by the river; but a number of beautiful country residences which command a fine view of the valley and eastern hill are located at various places on the steep slope of the hill to the west of the river. The village and country places are on the Cleveland and Eastern division of The Eastern Ohio Traction Company at a distance of about an hour and a quarter from the Public Square in Cleveland so that during the summer months it is not especially inconvenient for Cleveland business and professional men to reside in this charming region and attend to their daily duties in the city.

The valley on the eastern side of the river, opposite the village, is either very narrow or else precipitous cliffs rise almost from the water's edge. A short distance northeast of the car barn the traction line crosses a stream which has cut a deep and narrow gorge known as Dean's Gully in the steep face of the eastern hill. The banks of the Chagrin River at the mouth of this stream are alluvial and such is the nature of the brook's banks until a few rods above the traction trestle. The lowest rocks exposed in the stream are barometrically 70 feet higher than the Chagrin River and form the floor and low banks of the brook a few rods above the traction trestle. They are composed of soft, blue argillaceous shales, which are rather soft when wet, but harden somewhat on drying. In certain layers *Liorhynchus ohioense* n. sp. is common, perhaps the greater number of specimens occurring in about the lowest shales exposed. These specimens more nearly resemble small ones of *L. mesicostale* Hall than most specimens of this species (as for example specimens of *L. mesicostale* from the Ithaca formation at North Norwich, N. Y., which are in the American Museum). Still the plications on the Ohio specimens are broader, not raised so high and more rounded than on *L. mesicostale.* In addition to *Liorhynchus* an occasional specimen of a short and broad *Lingula* was found. On the bank of the stream a little farther up occasional harder layers about an inch in thickness occur in alternation with the soft, argillaceous shales. These shales are in the Chagrin formation and the base of the lowest outcrop is about 110 feet below the top of it. Uninterrupted exposures of these soft, blue shales which in the upper part contain a few thin harder layers about an inch thick, weathering to a rusty color, continue for about 20 feet. Then the narrow valley is choked by drift and alluvial deposits; but about 10 feet higher outcrops of soft blue argillaceous shale occur in the bed of the brook. A little farther up the stream is a bank of similar shale 20 feet high. Sixty feet higher than the shale in the bed of the brook just mentioned, blue sandstone about 2 inches thick occurs in the midst of blue shale, some of which is slightly arenaceous, but most of it is argillaceous. An occasional specimen of *Liorhynchus* was seen; but no other fossils.

Twenty feet above the outcrop just described is the lowest exposure of the Cleveland shale. The contact of the two formations is concealed; but the tougher Cleveland shale projects and forms a slight cliff on one of the steeper faces of the bank on the southern side of the stream. About 20 feet of the black, tough Cleveland shale is shown on the cliff, above which is a covered interval of about 15 feet when an 8-inch sandstone of the Bedford is reached. Apparently on this cliff it is not much more than 20 feet from the lowest exposure of the Cleveland shale to its top. This agrees fairly well with the thickness from the base of this outcrop to the top of the Cleveland shale which is clearly shown on the bank of the brook some rods above, an interval of about 25 feet according to the barometer. The section of this portion of the southern bank is as follows:

Lower Section on Bank of Dean's Gully.

No.		Thickness. Feet.	Total thickness. Feet.
4.	Covered slope	--	--
3.	Thin sandstone in *Bedford formation*	$\frac{2}{3}$	$35\frac{2}{3}$
2.	Covered interval, probably about to the top of the Cleveland shale	15	35
1.	*Cleveland shale.* Tough, thin shale, but contact with the Chagrin formation is not shown	20±	20

Farther up the brook on the northern bank the contact of the Cleveland shale and Bedford formation is perfectly shown. The bank here is steep, but the rocks are mostly covered with the exception of an occasional sandstone outcrop until the base of massive sandstone cliffs is reached which form its upper part. At this locality it is not clear that the base of this upper sandstone cliff is the base of the Berea sandstone; but farther up the stream, in the fall, the contact of the Bedford and Berea formations is clearly shown. The reading of the barometer, however, at the contact of the two formations is the same as at the base of the massive sandstone on the cliff 90 feet or so above the top of the Cleveland shale which appears to demonstrate that the base of the massive sandstone is the base of the Berea formation. The interval from the top of the Cleveland shale to the base of the massive sandstone and Berea formation was 93 feet by hand-level, which is the thickness of the Bedford formation. The barometer with a difference of only 12 minutes between the readings gave a difference of 85 feet for the interval. The detailed section of this entire bank is as follows:

Upper Section on Bank of Dean's Gully.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
10.	Top of bank composed of *Berea sandstone.* The layers forming the upper part of the cliff are thinner bedded than those in				

No.		Thickness Ft.	Thickness In.	Total thickness. Ft.	Total thickness. In.
	the lower portion, the lower one 2 feet or so thick. The thickness of this interval was 29 feet as leveled, and 25 feet by barometer. Base of Berea sandstone	29	--	125	--
9.	*Bedford formation.* Upper part of this interval covered. Near the base a layer of sandstone, with shales below	28	8	96	--
8.	Ledge of sandstone	1	4	67	4
7.	Mainly covered interval	26	--	66	--
6.	Ledge of sandstone about a foot or so in thickness	1	--	40	--
5.	Mostly covered interval	25	--	39	--
4.	A ledge of thin sandstone, 6 inches or more in thickness	--	6	14	--
3.	Zone partly covered, though composed mostly of shales; but about 2 feet above the base is a sandstone layer more than 2 inches in thickness, and at the base, one 2 inches thick	7	6	13	6
2.	Bluish-gray, rather soft shale, which extends to the base of the Bedford formation, making its total thickness 93 feet	3	--	6	--
1.	*Cleveland shale.* This is finely shown near the foot of the bank to the bed of the brook, and consists of coal-black, tough shale, with the usual characteristics of the Cleveland	3	--	3	--

Somewhat farther up the brook is the fall just below the highway bridge and in the bed of the brook at its base are bluish Bedford shales. About 20 feet higher in the lower part of the fall is a layer of bluish sandstone 1 foot 4 inches in thickness, while still 20 feet higher is the contact of the Bedford formation and Berea sandstone which is beautifully shown in the face of the fall. The upper part of the Bedford formation is composed largely of bluish argillaceous or arenaceous shales in which there are occasional sandstone layers some of which reach a thickness of 1 foot 4 inches; but as a rule they are thinner, rarely over 6 inches in thickness. In the lower part of the formation are some sandstones; but so much of the rock is covered that it is not apparent that sandstone predominates. Apparently the Euclid member is not well developed in the exposure along this brook, or rather the rocks have changed from the fairly thick sandstones on Euclid Creek to shales and thin-bedded sandstones. The barometer gave 85 feet for the thickness of the Bedford formation as measured in ascending the brook from the top of the Cleveland shale to the base of the Berea sandstone at the side of the fall with an interval of 33 minutes between the readings.

In the fall there is some 10 feet of Berea sandstone and above it cliffs of this formation rise from 20 to 30 feet higher. At this locality

an amphitheatre has been formed bounded by lofty walls from which the only egress is either by returning down the stream or by a path on the northern bank which runs for some distance backward along the cliff on or near the contact of the two formations and then steeply climbs the highest part of the cliff over the Berea sandstone. At this locality the Berea consists of heavy layers, showing marked examples of oblique stratification or cross-bedding, which alternate with thin-bedded ones. One of the layers in which the oblique bedding is very conspicuous has a thickness of 8 feet. The oblique stratification in the Berea sandstone of these cliffs was noted by Dr. Newberry who gave an explanation of the method of its formation together with a diagrammatic figure of the layers in his Cuyahoga County report.[1] Some of the lower layers of the Berea are very coarse-grained—a grit—and rather friable in texture, so that they resemble to some extent the Cussewago sandstone of Pennsylvania, which later will be described in this bulletin.

The contact of the Bedford formation and the Berea sandstone is shown on the path farther west along the cliff and from this horizon to its top the rock all belongs in the Berea with a thickness of 40 feet by the barometer which is the maximum estimate of its thickness in the cliff at the fall. In the stream above the highway is another but smaller fall which is formed by the top of the Berea sandstone. The top layer at the fall is pitted from the decomposition and leaching out of iron pyrites, as is almost universally the case with the top of the Berea sandstone. The barometer reading on the Berea sandstone at the top of the cliff mentioned above and at the top of the upper fall is the same, so that apparently 40 feet is about the maximum thickness of the Berea at this locality.

In the gutter by the county line highway just north of the stream is blackish shale which as weathered is more nearly brownish or brownish-black in color and represents the Sunbury shale. There is about 9 feet of covered interval from the top of the Berea sandstone to the base of this shale outcrop and then about 5 feet of shale is shown in the gutter; but evidently not reaching to its top. On this bank immediately above the fall is a covered interval of 18 to 19 feet when weathered and broken layers of thin-bedded sandstone project from the soil which apparently represent a ledge of sandstone on the upper part of this bank.

In the highway gutter on the south side of the stream, barometrically 20 feet above the top of the Berea sandstone, is a fine-grained, bluish-gray sandstone, about 5 feet of which is shown. This sandstone extends to the highway corners and is also shown a few rods from them on the road leading down the hill to Gates Mill. Beneath the sandstone in the highway gutter is shown 5 feet of a soft bluish-gray rather than

[1]Ibid., p. 199.

blackish shale. These sandstones on both sides of the stream represent the Aurora sandstone.

At the head of this gorge was formerly a saw and grist-mill owned by Mr. Davis and still earlier by Samuel Dean, from whom was derived the name of Dean's Gully for this gorge. This is the locality that Dr. Newberry briefly described as follows:

"At a saw mill, one mile east of Gates' Mill, a deep gorge cuts through the Berea sandstone, exposing the shale below. The grit here affords beautiful examples of cross stratification."[1]

For several rods along the stream above the top of the Berea sandstone in the fall the rocks are covered. Then thin layers of blackish shale appear and 5 feet higher by the barometer than the top of the Berea is a layer of bluish-gray sandstone from 1 inch to $1\frac{1}{2}$ inches in thickness. Immediately above and below this thin sandstone is bluish-gray to blackish shale. On the bank immediately above the thin sandstone about 5 feet of blackish shale is shown with loose thin flaggy sandstone above. Also in the bed of the stream and its low banks for a thickness of 5 feet by the barometer are nearly continuous outcrops of blackish shale; some of which, however, on the top or edges of the layers has weathered to a somewhat brownish color, or occasionally is even bluish-gray. These blackish shales with a thickness of from 10 to 15 feet are regarded as representing the Sunbury shale.

There is then a covered interval of about 5 feet by the barometer when the base of bluish-gray, fine-grained and thin-bedded sandstone is reached with soft bluish-gray shale immediately beneath it. This sandstone splits into somewhat even layers and with interruptions is shown along the stream for some distance with a thickness by the barometer of nearly 10 feet. This sandstone represents the Aurora and its uppermost exposure occurs in the bed of the stream above which the writer found no further outcrops.

On a small run which enters the main stream from the southeast some rods above the upper fall and barometrically 20 feet higher than the top of the Berea is an outcrop of bluish-gray, fine-grained sandstone, with a tendency to split into somewhat thin and even layers. About 6 feet of this sandstone is shown at this locality which also belongs in the Aurora. There is then a covered interval of about 20 feet when in the gutter of the highway leading to Scotland soft bluish-gray to blackish shales are shown. Ten feet of these shales is exposed according to the barometer and they belong in the lower part of the Brecksville shale.

No further outcrops were seen by the writer until the Sharon conglomerate was reached which forms the conspicuous ledges from northwest of Scotland around the hill to Chesterland Caves and probably its best exposure is to be seen in the cliffs just west of the dancing pa-

[1]Ibid., p. 199.

vilion at what is known as "the caves." Most of this rock contains numerous white quartz pebbles which vary in size; but some of them are rather coarse and to a certain extent the different sized pebbles occur in separate layers in the massive rock. There is also abundant evidence of cross-bedding in the faces of the massive ledges. The caves which have given popular interest to this particular part of the ledge are due to the enlargement of the natural joints in the rock. This enlargement is especially marked in some of the joints seen in the lower portion of the cliff which form the principal caves. At "the caves" there are almost vertical cliffs between 40 and 45 feet in height. At this locality the thickness of the rock from the lowest part of the cliff to the highest rock shown just east of its edge is 45 feet by the barometer and 48 feet by the hand-level. Various springs of pure water emerge from this conglomerate or its base along the course of the ledges and one of them just east of the dancing pavilion has been enclosed by the Chanler & Rudd Company and the water is bottled and sold in Cleveland. Another excellent spring is in the ledge above the ruins of the old cheese factory and not far to the northeast of the trolley station for Chesterland Caves. Farther along the ledge to the southeast across the highway and within only a few rods of Scotland is a portion of it that is very pebbly and also considerably decomposed by weathering, so that virtually it is only a fairly well consolidated gravel bank. This has been quarried to some extent and shipped to Cleveland where it is used for the drives on the Rockefeller grounds. The quarry has been carried into the ledge for some distance until the rear wall is now between 15 and 18 feet in height. The upper part of the quarry wall is a sandstone; but the pebbles increase downward until in the lower portion it is very pebbly. Cross-bedding is also shown and it appears that these very pebbly portions of the formation probably represent channel fillings produced by strong local currents which cut out the sand and brought in gravel.

The interval from the base of the ledges, which is probably about the base of the Sharon conglomerate, to the top of the Berea sandstone at Dean's Fall is smaller than the usual interval between the Sharon conglomerate and Berea sandstone. The distance from the ledges to Dean's Fall is about 1.4 miles in a northeast and southwest direction and the barometer gave a difference of 85 feet between the base of the cliff at "the caves" and the top of the Berea. The barometer was falling, however, and the interval between the two readings was two hours, so that it was undoubtedly an underestimate. Later readings between the top of the Berea and the base of the pit in the quarry northwest of Scotland gave a difference of 125 feet with an interval of three-fourths of an hour between readings. Again the difference between the base of the ledge above the old cheese factory and the top of the Berea sandstone, with one hour's interval in the readings, was 130 feet. These three localities of the Sharon conglomerate are at about

the same horizon. These estimates were checked by comparison with the topographic sheet of the Mentor quadrangle which gave, as near as could be determined, a difference in elevation between Dean's Fall and the base of the conglomerate at "the caves" of from 110 to 120 feet. The correction for dip was not determined; but it appears probable that the thickness of the Cuyahoga terrane in this section is toward 125 feet. It is to be remembered that Dr. Newberry gave the thickness of the Cuyahoga shale in the vicinity of Chagrin Falls, six miles to the south, as "only about 100 feet," and explained this diminution in thickness as "probably due to the erosive action of the currents which deposited the Conglomerate."[1]

The rocks exposed in Dean's Gully and the adjacent region may be represented by the following diagrammatic section:

Section from Chagrin River up Dean's Gully to Chesterland Caves.

536′		Top of ledges at Chesterland Caves
	48′	Sharon conglomerate
488′		
	125′±	Cuyahoga terrane
363′		
	10′ —	Aurora sandstone
353′		
	5′	Soft, bluish-gray shale
348′		
	15′ (?)	Sunbury shale
333′		
	40′	Berea sandstone
293′		
	93′	Bedford formation Partly covered
200′		
	20′	Cleveland shale
180′		
	110′±	Chagrin formation Mostly soft, blue shale, and there are several covered intervals
70′		
	70′	Covered to level of Chagrin River
0′		

On the western side of the valley and about opposite Gates Mill is a ravine known as Bear's Gully, the lower part of which is crossed by the highway and the upper portion by the electric railroad; but the greater part of the gully lies to the south of the highway.

[1]Ibid., p. 198.

Section of Bear's Gully.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Berea sandstone.* Upper portion of exposure on creek bank, above the trolley track, which is apparently about the highest rock shown. The upper portion as shown in the banks of this stream is rather thin-bedded, and where weathered, splits up into layers about an inch in thickness. Ripple-marks are not infrequent; a character that was noted in some of the sandstones in the upper part of the subjacent Bedford formation. The barometer gave a thickness of 40 feet from the highest outcrop to the base of the Berea, which is shown a little below the stone culvert on the north and south highway. This is probably about the thickness of the formation, since the same amount was obtained for the Berea in Dean's Gully, on the opposite side of the river.	40	275
3.	*Bedford formation.* The upper portion of this formation is well shown in the stream, and on its banks below the stone culvert, and consists mainly of sandy, bluish-gray shales, although there are some argillaceous ones, and layers of sandstone, some of which reach a foot in thickness. The shales, however, decidedly predominate; but they are bluish-gray in color, rather than reddish-brown, as stated by Dr. Newberry.[1] In this gully there are no reddish-brown shales, except as they may have been iron-stained on weathering; and it is to be noted that in the Chagrin Valley no exposures of the reddish or chocolate Bedford shales have been seen in the sections which the writer has studied. Near the base of the Bedford exposures is a very compact, fine-grained and hard layer, from 6 to 8 inches in thickness, which is evidently somewhat calcareous. This explains the source of the loose, calcareous blocks that were noticed lower in this gully, and probably its continuation furnished those seen in the stream west of Wilson Mills. The lowest exposures of the Bedford are sandstones, which evidently represent the eastern continuation of the Euclid member. The contact with the Cleveland shale is covered; but from the base of the lowest outcrops to the top of the Bedford, the barometer gave 90 feet, which is of course less than the actual thickness of the formation. This thickness, however, of 90+ feet for the Bedford formation, indicates a general agreement with the 93 feet obtained for it in Dean's Gully, on the eastern side of the river..	90+	235
2.	*Cleveland shale.* Black, bituminous shale, but neither the top nor bottom of the formation is shown. From the base of the lowest outcrop of the Cleveland shale		

[1]Ibid., p. 199, where he stated that in Bear's Gully "42 feet of reddish-brown shale (Bedford shale) are seen underlying it (Berea grit)."

No.		Thickness. Feet.	Total thickness. Feet.
	to the base of the lowest Bedford is by the barometer 30 feet, which is identical with the thickness obtained for this shale in the stream west of Wilson Mills	30±	145
1.	*Chagrin formation.* The exposures in this gully consist mainly of soft, blue, argillaceous shales; but there are also somewhat calcareous, rusty-colored, concretionary layers. From the lowest observed outcrop, which is not far south of the highway, to the first one of Cleveland shale is barometrically 115 feet	115	115

The formations exposed in Bear's Gully may be represented in the following diagrammatic section:

General Section of Bear's Gully.

275′		Top of section on creek bank above the trolley track
	40′	Berea sandstone
235′		
	90+′	Bedford formation
145′		
	30±′	Cleveland shale
115′		
	115′	Chagrin formation
0′		Lowest observed outcrops

The eastern bank of the Chagrin River not far above the highway bridge in Gates Mill is steep and rocky. The lower part, however, is more or less covered by talus; but the upper portion clearly shows thin sandstones alternating with shales. The bank is difficult to climb. The greater part of it, however, belongs in the Chagrin formation, although perhaps the highest portion is in the Bedford formation. At the eastern end of the dam is a bank of apparently bluish shales containing thin layers of sandstone, which is perhaps 30 feet high and in the Chagrin formation.

Chagrin Falls Sections.—Following up the Chagrin Valley $6\frac{1}{2}$ miles to the south of Gates Mill the locality is reached where the Chagrin River makes an abrupt turn in the direction of its course and changes from a northerly to a southwesterly direction. Near this point the Aurora Branch of the Chagrin River, the headwaters of which rise in Aurora Township in the northwestern part of Portage County some 14 miles to the southeast, enters the main river. The village of Chagrin Falls is located at the falls on the main river about 1.8 miles above its change in direction, while the river heads some 14 miles farther to the northeast

in the southeastern part of Chardon Township, Geauga County. Near the bend the river is crossed by the Chagrin Falls and Garrettsville Division of the Eastern Ohio Traction Company on a rather elevated bridge, about 50 feet above the river level, known as the High Level Bridge at Benleyville. Just below the bridge is a steep, rocky bank, some 55 feet in height, in the greater part of which the older rocks are shown.

Section at High Level Bridge.

No.		Thickness. Feet.	Total thickness. Feet.
3.	Bluish, somewhat arenaceous shale near top of bank, which weathers into small pieces	2	55½
2.	Covered interval	9	53½
1.	Upper portion of this division consists of thin, bluish shales, which break up into somewhat small pieces. At the head of a small fall is a sandstone layer 15 inches thick. Lower are bluish to bluish-gray shales, which alternate with thin-bedded sandstones. The base of the cliff shows blue to bluish-gray shales, alternating with thin, even-bedded, arenaceous shales to thin sandstones. A sandstone layer not much above the river level is fine-grained and gray, with a thickness of 1½ feet. The total thickness of this division, which extends to the river level is 44½ feet	44½	44½

The lithologic appearance of the rock in the above section suggests that it belongs in the Bedford formation and this is confirmed by stratigraphic evidence that will shortly be described. The Aurora Branch enters the Chagrin River not many rods above the High Level Bridge and Dr. Newberry's statement that "At the junction of the two branches of Chagrin River, 25 feet of the Berea grit are exposed" is misleading.[1] This outcrop is some little distance up the Aurora Branch; and apparently at the junction of the two branches and in that immediate vicinity only the Bedford formation of the Paleozoic rocks is shown. Dr. Newberry also stated that "The Bedford shale is here well shown below the Berea, though the bottom of the formation is not seen,"[2] apparently meaning at the junction of the two branches of the river and this statement is quite true for that general vicinity.

A few rods below the High Level Bridge a stream known as Deer Lick Creek enters the Chagrin River from the southwest. It has not yet cut down to the level of the Chagrin River so that a fall is formed in the rock bank, just before it enters the river. In the lower part of the fall is a compact, fine-grained sandstone layer of bluish color which is 1 foot 4 inches in thickness. The older rocks as shown along this stream, with the exception of the alluvial covered intervals, consist of bluish

[1]Ibid., p. 199.
[2]Loc. cit.

arenaceous, with some argillaceous, shales and a good many layers of sandstone. Some little distance up the creek in a small glen, the base of the Berea is reached and one reading of the barometer gave 55 feet from the level of the Chagrin River to the Berea sandstone. This fifty odd feet of rock represents approximately the upper half of the Bedford formation which may be described for this section as composed of bluish arenaceous shales with some argillaceous ones and layers of fine-grained, compact, blue sandstone. The occurrence of the base of the Berea sandstone 55 feet higher than the Chagrin River level apparently shows that the floor of the High Level Bridge is not much below the horizon of the Berea grit and that the section of the river bank just below the bridge all belongs in the Bedford formation.

The lower 2 to 3 feet of the Berea sandstone in the Deer Lick Creek glen is thin-bedded succeeded by coarser grained and soft sandstone. A portion of the lower part of the Berea sandstone is soft and reminds one somewhat in this character of the Cussewago sandstone of northwestern Pennsylvania.

Somewhat farther up the creek is the Deer Lick quarry where the top of the Berea sandstone is shown capped by the black, fossiliferous Sunbury shale. One reading of the barometer gave a thickness of 40 feet for the Berea sandstone; but Dr. Wilkinson obtained only 30 feet by leveling. The creek is, however, rather difficult to follow with a hand-level and the 40 feet is in closer agreement with the thickness obtained on the Aurora Branch, opposite the Independent Stone Company quarry, probably not more than three-fourths of a mile to the southeast.

The Berea grit has also been quarried near the track of the electric railroad some distance north of the Deer Lick quarry where, according to one reading of the barometer, it is 20 feet higher.

On the bank of Hoffman Brook (?) about opposite stop 33 and 25 feet higher than the top of the Berea sandstone are bluish-black soft shales with layers of sandstone perhaps ½ inch in thickness. This bank is above the horizon of the Aurora sandstone and in the lower part of the Brecksville shale. On the creek not far above stop 33 are two excellent banks of the Brecksville shale some 25 feet in height. These banks are composed mainly of soft blackish shale with an occasional layer of very thin sandstone in the lower part. The highest outcrop of the Brecksville shale seen occurs in the bed of Hoffman Brook a few rods above the Hiram House Camp and is bluish-gray in color and rather coarse in texture. Above this locality nothing but banks of boulder clay and other drift and alluvial deposits were seen. This gave from the top of the Berea grit to the highest outcrop of shale 105 feet by the barometer for the Cuyahoga terrane. As read from the trolley car, 100 feet was obtained for the same interval. This gives apparently at least 105 feet for the thickness of the Cuyahoga terrane and no doubt

it is somewhat greater since it is improbable that the shale above the Hiram House Camp is as high as the base of the Sharon conglomerate. The thickness of 105 feet, however, for the Cuyahoga terrane is in close agreement with Dr. Newberry's statement that in the vicinity of Chagrin Falls the Cuyahoga shale is "only about 100 feet thick; much thinner than any other known locality."[1]

On the Chagrin River and nearer the village, at a place where formerly a mill was located, is an outcrop of sandstone the layers of which vary in thickness from 1 to 1½ feet, while they alternate with bluish somewhat arenaceous shales which split into thin pieces. This outcrop is still in the Bedford formation; but it is to be noted that in this region there is a considerable amount of fairly thick-layered sandstone in the upper part of it which lithologically resembles somewhat the sandstone of the Euclid member.

The village of Chagrin Falls owes its existence to the fall formed by the lower part of the Berea grit, which furnished water power for the mills, and occurs just below the street viaduct. This was formerly known as the lower fall.

Section of Chagrin Falls.

No.		Thickness. Feet.	Total thickness. Feet.
2.	Massive sandstone, which forms the crest and upper half of the fall. There is about 8 feet of this sandstone which forms the lower part of the Berea. It is rather sharply separated from the subjacent Bedford shale	8±	14
1.	*Bedford formation.* Gray shale, which a little lower alternates with thin sandstones, that near the base of the falls approach a foot in thickness. The prominence of the sandstones in the upper part of the Bedford is to be noted in this section as well as in the others in the vicinity of Chagrin Falls	6±	6

Above the village on the eastern side of the river and opposite the paper mill is the Hannibal Goodale quarry described by Dr. Newberry[2] and now known as the Forsyth quarry. It is no longer, however, worked to any considerable extent. The following section may be seen in the quarry together with the overlying shale:

Section of the Forsyth Quarry.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Sunbury shale.* Black, bituminous shale, which frequently weathers on the edge to a rusty color, and is a massive shale under cover. The lower foot of the shale con-		

[1]Ibid., p. 198.
[2]Loc. cit.

No.		Thickness. Feet.	Total thickness. Feet.
	tains immense numbers of *Lingula melie* Hall and *Orbiculoidea herzeri* Hall and Clarke. There are also fragments of fish bones and scales, principally scales of *Paleoniscus*, and in addition, fragments of branching plant stems which are rather finely striated longitudinally, somewhat like *Cordaites*. The fossils are the most abundant in the lower foot of the shale, but they occur in considerable force for at least $2\frac{1}{2}$ feet above the base, and specimens were collected in the shales at the height of 4 feet	11	20
2.	Top of *Berea sandstone*. Massive, coarse-grained layer, friable rock, easily crumbling in the fingers, $3\frac{1}{2}$ feet thick. At the lower end of the quarry the massive upper layer splits into thin, rather irregular flags and there is no massive layer at top. The lower part of the quarry is composed of thin-bedded to shaly sandstone, part of which makes flagging. The flags show ripple-marks and some of the layers are worthless; $2\frac{1}{2}$ feet exposed	6	9
1.	Covered to river level	3±	3

Essentially the above section was published by the writer in 1902.[1] The shaly portion near the top of this quarry agrees fairly well with the lithologic conditions in quarry No. 9 at Berea where there is no heavy stratum at the top of the shaly sandstone.

This is one of the best localities noted in the Sunbury shale for collecting fossils where the two common species may be obtained in great abundance. Attention was first called to the fossils in the shale at this locality and Berea by Dr. Newberry who stated that "In both these places that portion of the Cuyahoga shale which immediately overlies the Berea grit contains myriads of *Lingula melia* [*e*] and *Discina Newberryi*."[2] The following notes were made concerning these two species:

Lingula melie Hall, abundant.

This species occurs in great abundance in the lower part of the shale at this locality. The various specimens show all the characters that were given by Hall in the description of it. Hall gave the proportion of length to width as about 3 to 2 and the specimens agree fairly well although there is some variation from the exact proportion. The following four specimens are typical:

Length	9.4 mm.	Width	5.3 mm.	
"	8.8 "	"	5.7 "	
"	7.3 "	"	5 "	
"	5.4 "	"	3.1 "	(small specimen).

The type specimens of this species, from Chagrin Falls, Ohio,

[1] Jour. Geology, Vol. X, p. 300.
[2] Geol. Surv. Ohio, Vol. I, p. 185.

which are illustrated by figs. 3 and 4 on pl. 1, Vol. IV, Pal. N. Y., were studied in the American Museum (No. $\frac{6413}{2}$ of that collection).[1] These specimens are not the smallest forms that occur in these shales; but those of medium size. Professor Whitfield referred the smaller ones to this species and the more pointed valves he considered the ventral and prolonged for the pedicle. If this be correct, then fig. 4 of the types is a ventral valve. The specimen has a more quadrate form than is shown by fig. 3, which is too pointed toward the beak.

The original specimen of fig. 3 has a length of 11 mm. and a width of 7.2 mm; while the original of fig. 4 is 9.5 mm. in length and 5.5 mm. wide. This measurement shows that in size the original of fig. 4 is almost identical with the first specimen listed in the writer's collection; while the original of fig. 3 is larger than any in that list. This last observation is important since it has been thought that some of the largest specimens at Chagrin Falls might belong to *L. cuyahoga* Hall. The type of this latter species (No. $\frac{6410}{1}$ of the American Museum), which is the original of fig. 5, pl. 1, Vol. IV, Pal. N. Y., is a rather quadrate form, highly convex with a median depressed line which is not shown on *L. melie.* The length of the type specimen of *L. cuyahoga* is 15 mm. and the width 10 mm., which shows that it is a larger form than probably any of the Chagrin Falls specimens. The majority of the specimens on a representative block from Chagrin Falls agree almost precisely with the original type of *L. melie* which is shown by fig. 4. Some of the larger specimens are very similar to others on the block with the types of *L. melie.* They are not large enough for the type of *L. cuyahoga* and Professor Whitfield agreed that they are *L. melie.* The study of the specimens of *L. melie* and *L. cuyahoga* shows that the majority, if not all, of the specimens collected at Chagrin Falls clearly belong to *L. melie.*

There are some of the smaller specimens in the American Museum from Chagrin Falls which are labeled *L. ligea* Hall (?) (No. $\frac{6411}{2}$); but these specimens probably belong to *L. melie.* Another tray (No. $\frac{6413}{1}$) with specimens of about the same size from Cuyahoga Falls, Ohio, is labeled *L. melie* Hall (?). It appears to the writer that if there is any question as to identity it will be concerning these smallest specimens, similar to or smaller than fig. 10, pl. 22, Vol. VII, Geol. Surv. Ohio, which Professor Herrick identified as *L. melie* Hall, which is 7 mm. long and 4.5 mm. wide. It is possible that these smallest specimens may be separated from *L. melie*; but, as already stated, Professor Whitfield believed that they belonged to this species.

Orbiculoidea herzeri Hall and Clarke, abundant.

This species is the second in abundance in these shales and is the one identified by Dr. Newberry and others as *Discina newberryi* Hall

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[1]The catalogue number given for this species in the Am. Mus. Bulletin of type specimens is $\frac{5077}{1}$ which is wrong. The correct number in the catalogue is $\frac{6413}{2}$.

or in later papers by the writer and others as *Orbiculoidea newberryi*. *Discina newberryi*, however, came from a higher horizon at Cuyahoga Falls, Ohio, and the Sunbury shale specimens in 1892 were named *O. herzeri* by Hall and Clarke.[1] The specimen of *O. newberryi* represented by fig. 18, pl. 4F, pt. I, Vol. VIII Pal. N. Y., from Cuyahoga Falls is in the New York State Museum; also the specimens for figs. 14, 15 and 16 of the same plate of *O.* cf. *pulchra* (the specific name *pulchra* was printed by mistake for *herzeri*) from Meadville, Pa.

A comparison of these specimens with the Ohio ones shows that the pedicle area of the Sunbury specimens is lower and not so broad as for *O. newberryi*, while the apex of the brachial valve is more central than in the latter species; both of which characters were given by Hall and Clarke as distinguishing *O. herzeri* from *O. newberryi* (loc. cit). A partly exfoliated specimen from Chagrin Falls shows a median septum on the brachial valve similar to the one represented on fig. 13 of pl. 4F., Pal. N. Y. The block, however, with the original of fig. 18 of *O. newberryi* also contains numerous specimens of apparently the same species and the inside of one of the brachial valves shows a median septum or ridge similar to that represented on fig. 13 of *O. herzeri*. These Ohio specimens were examined by Dr. Ruedemann who agreed in their identification as *O. herzeri*. The type of *O. newberryi* Hall is in the American Museum (No. $\frac{6417}{1}$), which is from a rusty colored sandstone at Cuyahoga Falls, Ohio, and is figured on pl. 1, Vol. IV, Pal. N. Y. Brachial valves of the Chagrin Falls specimens were compared with the original type specimens of figs. 11 a-c pl. 1, Vol. IV, Pal. N. Y. of *O. newberryi* which clearly show that the apex of the brachial valve is much nearer the margin in the type specimens of *O. newberryi*. The crushed specimens in the shale do not show this valve as more convex; but in reality as decidedly flatter. The type specimens are from sandstone and the greater flatness of those in the shales is probably due to crushing.

Dr. Girty has dropped the name *Orbiculoidea* for the group of Paleozoic Discinas, to which it was applied by Hall and Clarke, because the first species mentioned by d'Orbigny proves to belong to another genus (*Schizotreta*) and Hall and Clarke assumed that the second named species was the genotype.[2] Dr. Girty wrote as follows concerning the genotype selected by Hall and Clarke:

"The method here employed of determining the generic content of *Orbiculoidea* appears to be that so called, of residues, a system open to serious objection, and much more frequently found in use among botanists than zoologists. I believe that the rule among the latter, that unless a genotype is selected by the author the first-named species

[1]Pal. N. Y., Vol. VIII, pt. I, p. 126, f. n. and p. 178.

[2]See Bull. U. S. Geol. Survey, No. 377, 1909, pp. 18, 19 and ibid., No. 439, 1911, pp. 37, 38.

shall be employed is far preferable, and I propose to apply it in this case."[1]

The above case is apparently covered by the rules reported by the International Commission on Zoölogical Nomenclature and adopted by the Seventh International Zoölogical Congress in August, 1907. Article 30, section g of these rules states that "If an author, in publishing a genus with more than one valid species, fails to designate or to indicate its type, any subsequent author may select the type, and such designation is not subject to change. (Type by subsequent designation.)"[2] Section k of the recommendations to this article further says that "If some of the original species have later been classified in other genera, preference should be shown to the species still remaining in the original genus (Type by elimination)."[3] From the above rule it appears that Hall and Clarke had the right to select a type for the genus *Orbiculoidea* and since they did, that species is the genotype and the genus *Orbiculoidea* stands.

In place of *Orbiculoidea* Dr. Girty uses provisionally *Lingulidiscina* which was proposed by Whitfield (*Lingulodiscina*) for *Lingula exilis* Hall.[4] It has not yet been conclusively shown, however, that Whitfield's genus *Lingulodiscina* is identical with d'Orbigny's *Orbiculoidea*. Dr. Girty states that *Orbiculoidea newberryi*, which Schuchert in his synopsis of American fossil Brachiopoda referred to the genus *Lingulodiscina*,[5] "is certainly a member of the *Orbiculoidea* group."[6] This may have strengthened his opinion that these two genera are identical; but the reference of *O. newberryi* to *Lingulodiscina* was accidental, as is shown by the following quotation from a letter by Professor Schuchert to the writer, dated July 2, 1906: "Certainly I have made a mistake regarding *Orbiculoidea newberryi*, for it is not a *Lingulodiscina*. It is an error I can not account for. When I received your letter I remembered the species as a *Orbiculoidea*. Please make the change and I thank you for directing my attention to it."

In Professor Schuchert's synonymy of this species it is listed as "Œhlertella newberryi Hall and Clarke, Pal. New York, VIII, pt. I, 1892, p. 132, pl. 4 F, Fig. 18."[7] The writer, however, does not understand that Hall and Clarke on the page cited intended to refer this species to *Œhlertella* and the explanation of fig. 18, pl. 4 F appears under the title of *Orbiculoidea newberryi* Hall.

The top of the Berea grit is shown just below the dam; that is farther up the river than the Forsyth quarry, and is located immediately

[1]Ibid., No. 377, pp. 18, 19.
[2]Science, N. S., Vol. XXVI, 1907, p. 521.
[3]Ibid., p. 522.
[4]Bull. Am. Mus. Nat. Hist., Vol. III, 1890, pp. 121, 122.
[5]Bull. U. S. Geol. Survey, No. 87, p. 261.
[6]Ibid., No. 377, p. 19 and see No. 439, p. 36.
[7]Bull. U. S. Geol. Survey, No. 87, p. 261.

above the paper mill. It is rough and pitted, as is generally the case, while directly on top of it rests the black Sunbury shale, about 11 feet of which is shown on the southern bank at the end of the dam. The total thickness of the Berea grit from its base in the fall below the viaduct to its top below the Paper Mill Dam is 38 feet by the barometer. The upper part of the Sunbury shale is rather gray and overlying it on the southern bank of the river above the paper mill is a zone of thin-bedded, bluish, fine-grained sandstone alternating with shaly layers. This zone represents the Aurora sandstone and a thickness of about 6½ feet is shown on this bank. One layer of sandstone is about 9 inches thick, below which is a 6-inch layer of shale. The following section shows in regular order the rocks exposed just below and above the Paper Mill Dam:

Section at Paper Mill Dam.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
3.	Top of *Aurora sandstone* as exposed on southern bank just above the dam. Member composed of blue, fine-grained sandstones, alternating with shales. One layer of sandstone is about 9 inches in thickness, below which is a 6-inch layer of shale	6	6	21	4
2.	*Sunbury shale.* The upper part soft, grayish, argillaceous shale. Lower, it is a black, fissile, bituminous shale, somewhat slaty, and this portion is very fossiliferous	14	10	14	10
1.	Top of *Berea grit,* with very rough and pitted upper surface.				

A little farther up the river than the section just described and on its same bank, individual layers of the Aurora sandstone reach a thickness of about 1 foot and in places locally thicken to 1 foot 9 inches. It here makes a massive zone of sandstone which can very readily be depended on to separate the Sunbury from the Brecksville shale. At this locality there is a fairly steep bank rising from the level of the pond which gives one a clear idea of some 70 feet of rock as shown in the following section:

Section of Bank Opposite Paper Mill Pond.

No.		Thickness. Feet.	Total thickness. Feet.
6.	*Brecksville shale.* Soft, bluish shale shown on upper part of path, and similar lithologically to zone below	9	71
5.	Apparently all rather soft, bluish to bluish-gray shale, while some of it is also bluish-black in color. From the base of the Aurora sandstone to the top of this zone is 62 feet as leveled, and 60 feet by one reading of the barometer and 65 feet by another	25½	62

No.		Thickness. Feet.	Total thickness. Feet.
4.	Sandstone zone, composed of about three layers, with a total thickness of 8 inches, and the highest conspicuous one shown in the Brecksville shale on this bank	$\frac{2}{3}$	$36\frac{2}{3}$
3.	Bluish to bluish-black shale, which is mostly soft; but with occasional thin layers of sandstone	$29\frac{1}{2}$	36
2.	*Aurora sandstone.* It is rather massive and in part of fine texture and blue color. There is shown $6\frac{1}{2}$ feet of this zone; but the base is not clearly marked	$6\frac{1}{2}$	$6\frac{1}{2}$
1.	*Sunbury shale*	--	--

On the northern bank of the river above the paper mill and ice house the Aurora sandstone is shown; but from the opposite side of the river one can not tell whether the subjacent Sunbury shale is exposed or not.

Above the Paper Mill Pond, between the two dams, is what is called the Little Fall, but about all that can now be seen is a rapid. This rapid is formed by a bluish and rather massive sandstone which according to the barometer is on the same level as the outcrop of the Aurora sandstone on the river bank, not far above the lower Paper Mill Dam. The sandstone in this rapid is undoubtedly the Aurora; but it is at this locality unusually heavy and the grain is rather coarser than is generally the case, so that it resembles more nearly the texture of the Berea sandstone. This Little Fall or rapid is probably the one called the Upper Fall by Dr. Newberry, who stated that "At Chagrin Falls, the Berea grit forms the upper and lower falls,"[1] and he furthermore reported that "In some localities—as at Chagrin Falls and Bedford—a stratum of shale is interposed between the two divisions."[2] It is evident that at this locality the Aurora sandstone was mistaken for the upper part of the Berea grit while the interposed shale is the Sunbury. It will be recalled that the writer has made precisely the same interpretation of the upper sandstone and subjacent gray shale in Dr. Newberry's section of the Berea grit at Bedford.[3]

The upper dam is located not very far above the Little Fall or rapid and above this dam, on the western side (which corresponds to the northern one farther down stream) are shown banks of Brecksville shale of some height above the level of the pond, from which an occasional layer of thin sandstone projects.

The individual sections described above when combined will furnish the following general section for the rocks extending from the base of the Lower Fall to the top of the bank opposite the Paper Mill Pond at Chagrin Falls:

[1]Geol. Surv. Ohio, Vol. I, p. 198.

[2]Ibid., p. 187.

[3]See his section on p. 197 of ibid, and the writer's interpretation in Jour. Geol., Vol. X, 1902, pp. 298, 299.

General Section of the Formations at Chagrin Falls.

130′		Top of exposed shales on bank opposite Paper Mill Pond	Orangeville formation Nearly 86 feet shown
	$64\frac{1}{2}$′	Brecksville shale	
$65\frac{1}{2}$′			
	$6\frac{1}{2}$′	Aurora sandstone	
59′–			
	$14\frac{5}{6}$′	Sunbury shale	
44′			
	38′	Berea sandstone (according to barometer)	
6′			
	6′	Bedford formation (Upper part of formation as shown in lower part of Lower Fall)	
0′			

Sections on Aurora Branch of Chagrin River.—The Aurora Branch of the Chagrin River enters that river only a short distance above the High Level Electric Bridge at Benleyville, and only a few rods above the lowest bridge on this river rocks are shown in the bed and on the banks of the stream. Some sandstone layers form a small fall not far above the bridge and on the eastern bank above the fall the Berea sandstone is shown.

Section at Lower Fall in Aurora Branch.

No.		Thickness. Feet.	Total thickness. Feet.
5.	Base of *Sunbury shale* in small run on eastern bank of Aurora Branch. Black, slaty, very fossiliferous shale of which about the lower foot is shown	1±	74
4.	*Berea sandstone.* Top and upper portion is well shown, but the contact with the Bedford formation is concealed. The Berea is fairly massive and thick-bedded, with its usual texture and some cross-bedding. It forms ledges on the side of the bank some distance above the stream, and the top is shown in the small gully just above the turn in the highway. The lower part of this interval is covered, in which is the contact between the Berea and Bedford formations. Farther up the river, near the Independent Stone Company quarry, there is shown 26 feet of mostly bluish shales beneath the Berea grit, all of which is above zone No. 3 of this section. This apparently indicates, that in this zone of 67 feet, not more than 41 feet is to be referred to the Berea sandstone	67	73 –
3.	In *Bedford formation.* Sandstone forming top of small fall, above which is rather soft, bluish, argillaceous shale. The sandstone is bluish-gray, rather coarse-		

No.		Thickness. Feet.	Total thickness. Feet.
	grained, and the top of the upper layer shows ripple-marks. The upper layer of sandstone is 11 inches thick, below which is a shaly parting of 3± inches, and then the lowest and thickest part of the zone	$3\frac{1}{4}$	$5\frac{2}{3}$
2.	Bluish, arenaceous shale	$1\frac{5}{6}$	$2\frac{1}{2}$—
1.	Compact, bluish-gray, rather fine-grained sandstone	$\frac{7}{12}$	$\frac{7}{12}$

The texture of the sandstones in this small fall is more like that of the Euclid sandstones than the Berea and they belong in the upper half of the Bedford formation. This is another locality in the Chagrin Falls region in which sandstone layers of considerable thickness were noted in the upper portion of the Bedford formation. The reference of these lowest outcrops in the Aurora Branch to the Bedford formation is in harmony with the views of Dr. Newberry, for he stated that "The Bedford shale is here at the junction of the two branches of the Chagrin River well shown below the Berea, though the bottom of the formation is not seen."[1]

Some distance farther up the river and on its eastern side is the old quarry of the Independent Stone Company where the massive Berea sandstone, the Sunbury fossiliferous, black shale and superjacent Aurora sandstone are well shown. The contact of the Berea and Bedford formations is finely shown on the western bank of the river about opposite the quarry, below which are the upper bluish shales of the Bedford formation.

Section at the Independent Stone Company Quarry.

No.		Thickness. Feet.	Total thickness. Feet.
6.	*Brecksville shale.* Fine, bluish-black shale, with an occasional thin sandstone, varying from 3 to 4 inches in thickness	10±	$97\frac{2}{3}$
5.	*Aurora sandstone.* Mainly sandstone zone, with shale partings, bluish-gray in color and rather fine-grained	$7\frac{2}{3}$	$87\frac{2}{3}$
4.	*Sunbury shale.* Black, bituminous, thinly laminated and very fossiliferous in the lower part	12	80
3.	Top of *Berea sandstone*, which has a rough and pitted surface. A total thickness of 35 feet and 5 inches is shown in the quarry, which does not reach the bottom of the formation. It may be subdivided into 4 zones, the upper one of which consists of a variable number of layers of thinner-bedded sandstones than the lower ones, with shaly partings and a thickness of $6\frac{1}{2}$ feet. At its base, a shaly parting below which is a course of massive rock, $9\frac{1}{2}$ feet thick. Another shaly parting, beneath which is a similar course of massive sandstone, 9 feet		

[1]Geol. Surv. Ohio Vol. I, p. 199.

No.		Thickness. Feet.	Total thickness. Feet.
	8 inches in thickness. This is not separated by any definite shaly parting from the lowest course of massive sandstone in the quarry, which is 9 feet 9 inches in thickness. The upper part of this quarry, and the subjacent bank, which is composed of the Sunbury shale, Aurora sandstone and lower part of the Brecksville shale, is well shown in Plate LIV	$35\frac{1}{2}$—	68
2.	Interval between base of quarry and base of formation which, judging from the section on the opposite side of the river, probably amounts to $6\frac{1}{2}$ feet or more	$6\frac{1}{2}\pm$	$32\frac{1}{2}$
1.	*Bedford formation.* Upper portion well shown on the river bank, which consists mainly of bluish, arenaceous shales, with a thickness to water level of about 26 feet. This shale is all above the sandstone zone which makes the small fall some little distance down the river	26	26

The contact of the Berea grit and the Bedford formation is beautifully shown on the western river bank about opposite the northern part of the Independent quarry and just above a run that enters the river from the west. A great depression in the upper surface of the Bedford has been filled by the coarse deposits of the Berea. This may be considered as an immense channel filling in the upper surface of the Bedford and as another example of the marked disconformity between the two formations. The Berea sandstone in the filling extends down to within about 2 feet of the river level at low water. Just above the filling is the nearly vertical wall of Bedford bluish shales and fairly thin sandstones, the thickest perhaps 6 inches, which extend up the bank 20 feet before reaching the base of the Berea. The channel filling of Berea sediments in the upper Bedford, just below the above mentioned cliff, goes down at least 15 feet below the top of the formation on that part of the bank. All these measurements are estimates as seen from the opposite side of the river.

The river bank and a small run opposite the northern end of the Independent Stone Company quarry furnish an interesting section which will now be described. This run is only a short distance above the rock upon which is the carved figure of a woman, known as Squaw Rock, and below the channel filling just described.

Section in Run Opposite Independent Stone Company Quarry.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
14.	*Brecksville shale.* Blackish shale, which extends up the run to the highway bridge	24	6	131	3
13.	Very thin layers of sandstone, from one-				

Independent quarry on Aurora Branch showing upper part of Berea grit, Sunbury shale. Aurora sandstone and lower part of Brecksville shale.

No.		Thickness Ft.	Thickness In.	Total thickness. Ft.	Total thickness. In.
	fourth to one-half inch thick, which weathers to a rusty color	--	3	106	9
12.	Bluish-gray sandstone, weathering into thin layers	--	3	106	6
11.	Black, argillaceous shale	15	--	106	3
10.	Blue, fine-grained sandstone	--	$3\frac{1}{2}$	91	3
9.	Blackish, argillaceous shale	3	$2\frac{1}{2}$	90	$11\frac{1}{2}$
8.	Blue, fine-grained sandstone	--	4	87	9
7.	Zone of mainly blackish shales with some very thin, bluish-gray, arenaceous ones to very thin, sandstone layers, one-fourth inch or less in thickness	5	3	87	5
6.	Bluish-gray, thin-bedded, fine-grained sandstone	--	$4\frac{1}{2}$	82	2
5.	Bluish-black, slaty shale	1	2	81	$9\frac{1}{2}$
4.	*Aurora sandstone.* Blue, fine-grained sandstone, with some thin shale partings, one of which is $2\frac{3}{4}$ inches thick; but the zone as a mass is mainly blue sandstone	6	$7\frac{1}{2}$	80	$7\frac{1}{2}$
3.	*Sunbury shale.* Black, bituminous shale, which is very fossiliferous in the lower part, and at the base are some tough layers	10	2	74	--
2.	*Berea grit.* Upper part composed of even layers like those in the quarry across the river. Ripple-marks occur in the upper third of this zone. Below are three massive layers, similar to those in the quarry. Stone rather coarse-grained, with some cross-bedding, which is marked in the lower part. The lowest part of the formation is rather coarse-grained and friable, in texture resembling the Cussewago sandstone of Pennsylvania. The sandstone on the southern bank runs down into the bed of the stream near its lower end, while the blue Bedford shale runs up the bank on the northern side of the stream, and is still higher on this western bank of the river a little below the run. The Bedford also rises somewhat on the southern bank of the run near its mouth. It appears that this stream has cut its course across an old channel filling in the upper surface of the Bedford formation. The contact is so sharp and steep between the sandstone and shale that a fault has been suggested as an explanation for the structure both in the run and on the bank of the river above, which has already been				

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
	described, but it appears now, that in both localities, channel fillings in the upper surface of the Bedford are shown. In fact, it is probable that these two examples of channel filling are in one and the same channel, though it was not possible to prove this inference. The Berea sandstone, as measured in the lower part of the run, varies in thickness from 41 feet 10 inches to 64 feet 4 inches in the high cliff on the south side. Probably the 42 feet is nearer the average thickness of the Berea sandstone in this region, and the greater thickness of 64 feet is due to the addition at the base of some 22 feet, which represents the thickness of the filling in the old channel----	41	10	63	10
1.	*B e d f o r d formation.* Bluish, arenaceous shales, which are rather coarse, and all above the sandstone zone which forms the small fall farther down the river. Eighteen and one-third feet of these shales were obtained from the river level to their top in this run; but on the cliff just below the run, 22 feet was measured, where the base of the Berea is higher---	22	--	22	--

This section shows very clearly that the thickness of the Berea grit near the lower end of the Aurora Branch varies from nearly 41 to over 64 feet and that the 25 feet reported by Dr. Newberry "at the junction of the two branches of Chagrin River"[1] did not represent the entire thickness of the formation. This lower part of the Aurora Branch, between the two highway bridges, is a most interesting gorge from a stratigraphic standpoint and is well worth studying.

The sandstone zone which overlies the black shale that is called Sunbury in these sections is named the Aurora sandstone from the outcrops shown in Independent quarry and in the run entering the river from the west. One of these localities is very near the river bank and the second one only a comparatively short distance from it, so it appears that Aurora, derived from the name of this river, Aurora Branch of the Chagrin River, is an appropriate name for it. In the quarry section, zone No. 5 with a thickness of $7\frac{2}{3}$ feet, and in the section on the opposite side of the river, zone No. 4 with a thickness of more than $6\frac{1}{2}$ feet, represent this sandstone. In both sections thin sandstone strata occur at higher horizons in the Brecksville shale; but the main mass of the rock is a blackish shale and not a sandstone as in the case of the zone to

[1]Ibid., p. 199.

which this name is applied. In many of the sections in northern Ohio there is a sandstone zone at about this horizon between the lower black Sunbury-like shale and the higher blackish or bluish-black Brecksville shale. For this reason the zone seems sufficiently important stratigraphically to receive a geographic name. In the stratigraphic discussions of the various sections such a name is of assistance in referring to the zone which is considered a member of the Orangeville formation. The writer's first choice for the type section for this member was a different locality, as, for example, the section on Chippewa Creek above Brecksville, or on the Chagrin River above the Paper Mill at Chagrin Falls; but unfortunately all these geographic names had already been applied to different geologic terranes and consequently were not available. So far as the writer is aware the Auroral series of Rogers is the only geologic name similar to that of Aurora sandstone. Since the names are not identical and the former one has almost passed out of geologic literature, except in a historic sense, it appears to the writer that the term Aurora sandstone is an appropriate name for this member of the Orangeville formation.

The Aurora Branch was followed for several miles above the Independent Stone Company quarry in the hope of finding additional sections of the Carboniferous formations; but in large part the banks are composed of either glacial or alluvial deposits. Boulder clay, stratified sand deposits and beds of gravel form various banks of considerable height.

At the iron bridge over the Aurora Branch 1.6 miles north of Geauga Lake are fine banks of Brecksville shale in which are some thin, harder layers apparently of sandstone. Above the bridge is a bank of this shale of bluish-gray to blackish color which is probably from 30 to 40 feet in height. The barometer, with an interval of about 3½ hours between readings, made the bed of the river at the iron bridge 55 feet higher than the top of the Berea grit in the Independent Stone Company quarry.

Not far north of the iron bridge a creek enters the Aurora Branch from the east in the lower course of which are rather extensive glacial deposits. On the highway climbing the hill, to the south of the creek, ledges of Sharon conglomerate are reached at a barometric elevation of 185 feet above the bed of the creek and 200 feet higher than the top of the Berea grit in the Independent Stone Company quarry. Frequent ledges of the conglomerate occur until the summit of the high ground is reached, 45 feet higher than the lowest ledge of the conglomerate. The lowest ledge of the Sharon conglomerate was also reached on the highway to the north of this creek and about one mile west of Bainbridge at approximately the same elevation as on the high ground to the south of it. A ledge of the Sharon conglomerate is also shown on the highway to the southeast of Geauga Lake and another one on

the road toward Centerville Mills to the east of the Erie Railroad. Geauga Lake is a beautiful lake of small size which is fed largely by springs and furnishes a body of pure and excellent water.

At Centerville Mills on the southern border of Bainbridge Township and 2.7 miles south of Bainbridge Village a stream has cut a gorge through the lower part of the Sharon conglomerate, which is bordered by steep ledges. The barometer gave 30 feet from the base of the exposed conglomerate to the top of the ledges. Part of the walls are composed of somewhat imperfectly defined layers of rock in which are numerous and coarse white quartz pebbles, while the remainder is simply a coarse-grained sandstone or grit. As a result of undercutting and weathering the rock breaks off in great blocks from the steep sides of the gorge and lies along the side of the creek. The barometer with an interval of 3 hours between readings gave the base of the exposed conglomerate in this gorge as 70 feet lower than the lowest ledge on the hill east of the iron bridge over the Aurora Branch. If the lowest exposure seen at each of these localities represents the base of the conglomerate, then in the southern part of Bainbridge Township there is a dip of about 32 feet per mile to the southeast. It is also evident that all of the higher ground of this township is underlain by the Sharon conglomerate, as was represented on the Geological Map of Ohio by Dr. Newberry.

CHAPTER III

LAKE AND GEAUGA COUNTIES

From Chagrin Falls to the mouth of the Chagrin River, Geauga County and the greater part of Lake County lie to the east of its valley. In these two counties also lies the most northern extension of the plateau of northern Ohio to the east of the Chagrin River and to the south and west of the Grand River. This plateau is really the western continuation of the one covering southern New York and northwestern Pennsylvania which has been deeply trenched by the Grand River and its tributaries on the north and those of the Mahoning River on the south.

On the western, northern and eastern side of this plateau in the two counties above named, are various prominent and well known cliffs of the Sharon conglomerate, as at Chesterland Caves, Little Mountain, which is an isolated outlier of the conglomerate, Thompson Ledge and Nelson Ledge in the northeastern township of Portage County which is adjacent to Geauga on the south. On this plateau are the headwaters of numerous streams which in their descent have cut gorges of considerable depth, part of which are bordered by outcrops of Paleozoic rocks. Some of these are narrow and bordered by steep and high rocky banks which afford excellent opportunities for studying the formations exposed in them. Geauga County is well watered, contains numerous excellent springs and on account of its elevation and comparative nearness to Lake Erie (14 miles) is salubrious in summer and one of the best sections of the State for a summer home. There are several small villages on the highland the two principal ones being Burton and Chardon. The last named town is the county seat of Geauga County and is reached by the New Castle Division of the Baltimore and Ohio Railroad from Youngstown and Warren on the south, or Painesville on the north, and the Cleveland and Eastern Division of the Eastern Ohio Traction Company from Cleveland. The town is located on one of the outliers of the Sharon conglomerate with excellent drainage in all directions, with about as high an elevation as any portion of the adjacent highland (1,300 feet above sea level at the center of the village), so that in summer it is generally comparatively cool for Ohio.

The principal streams in the western part of this area are the upper part of the Chagrin River and the East Branch Chagrin River, which enters the main stream about one mile south of Willoughby. The

course of the Chagrin River has already been described and the first one to be considered in this chapter will be the East Branch with its tributaries and the adjacent country.

Section of Penitentiary Glen. — This stream enters the East Branch at Kirtland, the seat of the first Mormon temple, in the northern part of Kirtland Township. About two miles to the southeast of Kirtland is that portion of the stream known as Penitentiary Glen or "the rocks," below the house of Mr. Hafla. A fall occurs not far below the highway, which crosses the upper part of the stream, and below this fall the stream has cut a narrow trench in the Berea grit with rocky, curving walls first on one side and then on the other of its course.

Penitentiary Glen Section.

No.		Thickness. Feet.	Total thickness. Feet.
2.	*Berea sandstone.* Coarse-grained, brownish-gray to gray in color, and on weathering is often greatly iron-stained. A large part of the upper portion is strongly cross-bedded. In the upper part of the bank the cross-bedded layers are very thick, but lower in the glen they are thinner. From the top of the highest part of the bank, which is still the Berea sandstone, to the base of the formation, is 40 feet by the barometer and 38 feet by level	38	76
1.	*Bedford formation.* The contact of the two formations is shown in a small fall, and on the cliff, at one side of the stream. It is composed of bluish-gray to gray, arenaceous shales and thin-bedded sandstones. The sandstones are rather thicker in some layers and form a greater proportion of the rocks of the formation than in the sections to the west of the Chagrin River. From the lowest outcrop seen in the creek, which is probably not the base of the formation, to the base of the Berea sandstone, is 25 feet according to one reading of the baometer or 38 feet as leveled by Mr. Flory	38 (?)	38

Near the headwaters of this stream and about 2.8 miles southeast of Kirtland is a high rounded, isolated hill known as Pearson's Mountain. According to the topographic map its elevation is a little more than 1,200 feet above sea level and by the barometer its top is 220 feet higher than the highest outcrop of the Berea sandstone. It is capped by the Sharon conglomerate; but the rounded summit is more or less completely covered by trees or grass and there are no favorable exposures of the conglomerate.

Section Near Mitchells Mill.—The old Mitchells Mill (near which is the present one of Maltby) is located in the western part of Chardon

Township not far from where the East Branch of the Chagrin River turns from its northerly course toward the west. In this neighborhood part of the river banks are fairly high and composed of the shales and thin sandstones of the Chagrin formation. Very near where the river changes the direction of its course Weller Creek enters from the north-east and along the lower half of its course its banks are bordered by Paleozoic rocks. The banks farther up the stream, at least as far as seen, are composed of alluvial and drift deposits and glacial boulders of crystalline rock are abundant at various localities.

The highest outcrop of the older rocks seen on the creek occurs but a short distance below its fork, where the following section near the base of the Bedford formation is shown on its western bank:

Upper Section of Weller Creek.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
6.	Blue sandstone at top of bank	--	5	4	11
5.	Blue shale	1	1	4	6
4.	Blue, fine-grained sandstone	--	$3\frac{3}{4}$	3	5
3.	Blue shale, argillaceous and slightly arenaceous	2	6	3	1
2.	Blue, fine-grained sandstone	--	2	--	7
1.	Blue, soft shale to bed of creek	--	5	--	5

This section is known to be near the base of the Bedford formation since after a covered interval of 10 feet below, the Cleveland black shale is shown in the bed and bank of the creek.

The following is the complete section of the Paleozoic rocks shown on Weller Creek:

Complete Section of Weller Creek.

No.		Thickness. Feet.	Total thickness. Feet.
6.	*Bedford formation.* Only a few feet of blue, fine-grained sandstones and shales near the base of the formation exposed	5—	138
5.	Covered interval	10	133
4.	*Cleveland shale.* Massive, black, typical Cleveland shale is shown along the creek, with a thickness of 5 feet barometric from the lowest to the highest outcrop. In the bed of the creek, and on the eastern bank, a little above the lowest outcrop, 2 feet is shown in continuous section	5	123
3.	Covered interval. One reading of the barometer made this interval 25 feet and a second one 10 feet, and 15 feet has been used in this section	15	118
2.	Top or near top of *Chagrin formation.* At top of cascade, in creek on the Silver Lance farm of Adam Knierim, above the stone highway viaduct, near School-house		

No.		Thickness. Feet.	Total thickness. Feet.
	No. 6. The cascade is formed by a blue, thin sandstone, just below which is blue shale. In the sandstone are numerous specimens of one form of *Spirophyton* (*Taonurus*) (the one with the comparatively long and nearly parallel sides), while the blue shale just below the sandstone contains an occasional specimen of *Spirifer disjunctus* Sowb., *Camarotœchia* cf. *eximia* Hall and *Grammysia* sp. A few rods below the viaduct is a much higher cascade, the crest of which is made by a thin sandstone, perhaps 6 inches thick, but the cascade and the banks below are composed mainly of blue, argillaceous and arenaceous shales, which contain very few fossils, and only an occasional specimen of poorly preserved *Spirifer disjunctus* Sowb. was seen. The cascade and banks of the gorge show typical outcrops of the Chagrin formation. For this interval, one reading of the barometer gave 35 feet and another 20 feet, so that an average, or 28 feet, has been used for this section	28	103
1.	From the foot of the cascade to the level of the East Branch the rocks are fairly well exposed along the creek, and belong in the Chagrin formation. The barometric reading was taken at water level, on the river opposite Hayden's watering trough, and gave 75 feet from the foot of the cascade to river level	75	75

In the above section the top of the upper cascade in the Chagrin formation which is comparatively near the top of the formation is, according to the average of two barometric readings, 325 feet below the base of the Sharon conglomerate as shown on the highway 1.4 miles to the southeast near Chardon Center. This 325 feet represents for this section the approximate total thickness of the Cleveland shale, Bedford formation, Berea sandstone and Cuyahoga terrane.

On the highway leading from School-house No. 6 and the Knierim farm to Chardon Centre the Paleozoic rocks are concealed until after passing the three corners and the house of L. A. Rider. The rocks shown along this road may be tabulated as follows:

Section Along Highway Northwest of Chardon Centre.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Sharon conglomerate.* Exposed by side of highway, northwest of School-house No. 4, in small quarry to the north of the road, and its base is shown in highway gutter a few rods below the house of Mr. Austin Hayden. This is shown to be the base of the conglomerate by comparison with the record of the upper part of the well drilled at the Austin Hayden house, which passed through 15 feet of conglomerate and sandstone, and the barometer gave the same thickness for the interval from the mouth		

No.		Thickness. Feet.	Total thickness. Feet.
	of the well to the base of the ledge in the highway gutter. Some of the conglomerate contains numerous quartz pebbles, part of them of fairly large size, and other portions are really only a coarse sandstone to grit.	15	443
4.	Covered interval. (The upper 42 feet, however, of this interval is shown by the Hayden well record to consist of shale and blue sandstone)	55	428
3.	In the gutter, opposite the first house below Hayden's (that of Mr. H. M. Burr), are shown thin, grayish sandstones, which are much shattered. Below are soft, bluish-black, argillaceous shales, with an occasional sandstone layer an inch or less in thickness. These shales represent the Brecksville, and are exposed as far as the house of Mr. L. A. Rider, a few rods above the three corners, and a short distance beyond it	57	373
2.	Covered interval to top of cascade in Weller Creek, above the stone viaduct on the Adam Knierim farm, which is comparatively near the top of the Chagrin formation. In the lower part of the interval, in the steep road banks southeast of the creek, are boulder clay and other drift deposits	213	316
1.	*Chagrin formation.* From the top of the cascade to the level of the East Branch of the Chagrin River	103	103

The measurements of intervals in the above section are mainly barometric, but apparently not far from correct, since the difference in altitude between the river level and the top of the hill at Mr. Hayden's is 430 feet as nearly as can be determined from a photographic copy of the Mentor topographic sheet. It will be noticed that there is a difference of but 13 feet in the two estimates and it is not certain but that a clearer copy of the topographic sheet, so far as the river valley is concerned, will add a little to the estimate based upon it. In the above section the thickness of the interval from the top of the cascade (No. 1) to the base of the Sharon conglomerate (No. 5) is 325 feet. On another day the barometer gave 335 feet for the same interval and on the third day 320 feet.

The well record at the house of Mr. Austin Hayden, about two-fifths of a mile northwest of Chardon Centre, has already been mentioned. The complete record is as follows; the measurement furnished by Mr. Hayden.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Sharon conglomerate.* Sandstone to grit and conglomerate	15	57
2.	Top of *Cuyahoga terrane.* "Soap-rock" of the driller, probably a soft shale	12	42
1.	"Blue sandrock" of driller, a blue sandstone to bottom of well	30	30

The lower 42 feet of this record corresponds to the upper 42 feet of the covered interval in No. 4 of the highway section and leaves only about 13 feet of this zone unknown. It will be remembered that at the top of No. 3 in the highway section as shown in the gutter are thin grayish sandstones and it is not improbable that the greater portion of the unknown part of the covered interval is also composed of sandstones. This indicates that near the top of the Cuyahoga terrane in this region there is a sandstone zone perhaps 45 feet in thickness, which probably represents the Sharpsville sandstones of Pennsylvania in which case it is evident that in this region the Cuyahoga terrane does not extend much above their top when the base of the Sharon conglomerate is reached.

North from Chardon Centre and a few rods north of the Charles Diedrich house the Sharon conglomerate forms the floor of the road for a short distance. It has a smooth glaciated surface on which are striæ, some of which are so coarse that perhaps they might be termed small furrows, which run N. 20° E. and S. 20° W. A little below, a small cut in the conglomerate has been made for the highway and it is also shown somewhat lower in the gutter. The upper portion of the outcrop is mainly a coarse grit with some quartz pebbles; but near the base the quartz pebbles are numerous and it is a typical conglomerate. The thickness of the conglomerate shown in this ledge is about 30 feet by both the barometer and level. What was taken for the base of the conglomerate, however, according to the barometer is about 15 feet lower than on the road below Austin Hayden's, less than one-half mile to the northwest.

Stebbins Gulch. — This glen is the most interesting geological locality in Chardon Township and one well worthy of careful study. It is supposed to be the locality mentioned by Mr. M. C. Read in his report of Geauga County as the "Big Gull" in which he stated that "the Berea grit is finely exposed."[1] The stream enters the East Branch from the east not far above the house of Mr. J. J. Tate and about three-tenths of a mile south of the old Mitchells mill. In a direct line the upper exposures of rocks on the stream begin at a distance of about 3.2 miles to the northwest of Chardon and one mile southwest of Chardon Centre. The highest outcrops of Carboniferous rocks seen on the stream occur some distance below the north and south road which nearly reaches it at the house formerly occupied by C. Hayden and later by Barnes. For some distance down the stream from this locality the banks are composed of alluvial or drift material until in the pasture above the woods bordering the "Gulch" bluish shales and thin sandstones of the Cuyahoga terrane are reached. Farther down the stream it has cut

[1]Geol. Surv. Ohio, Vol. I, p. 524.

a deep and narrow trench in the soft, massive Berea sandstone which is deeper and broader after it has cut completely through the Berea sandstone and its bed lies in the Bedford and Cleveland formations. The Berea sandstone forms heavy cliffs which border the stream for some distance and in places it is undercutting so that the sandstone projects over the water. The basal layers of the Berea form a pretty fall and farther up the gorge is a cascade over the Berea sandstones. It is a locality well worthy of a visit from either the scenic or geologic standpoint.

Section of Stebbins Gulch.

No.		Thickness. Ft.	In.	Total thickness. Feet.
15.	*Brecksville shale.* The highest outcrops seen on the stream consist of bluish shale, part of which is argillaceous, and arenaceous shales to thin, bluish sandstones, shown in the bed of the stream and low bank. A few rods farther down it is a bank about 10 feet high, the top of which, by the barometer, is at about the same level as the highest outcrops noted in the stream bed, which is composed mainly of shale, but contains some layers of bluish-gray, fine-grained sandstone. There are two rather conspicuous sandstone layers from $4\frac{1}{2}$ to 6 inches in thickness, separated by from 2 to 3 inches of shale, and still higher is another one about 3 inches thick. These sandstones are only about 25 feet above the base of the Brecksville shale, and are rather thicker and more conspicuous than generally noted at so low an horizon in it. Similar thin-bedded, compact ones, which have perhaps *crept* several feet down the bank, may be seen on the northern side of the "Gulch," opposite the upper outcrops of the Berea sandstone, and between 20 and 30 feet up the bank. Farther down the stream are some apparently calcareous, rusty, concretionary-like layers. Still farther is a bank some 20 feet high, composed of bluish-black, fine shale, with an occasional sandy layer in the lower part, varying in thickness from a fraction to perhaps 1 inch. This bank has the general lithologic appearance of the typical Brecksville shale	32	--	306
14.	*Chardon sandstone.* On the northern bank is a somewhat shattered ledge of rather			

No.		Thickness Ft.	In.	Total thickness. Feet.
	thin-bedded and shaly sandstone, but with some layers from 8 to 10 inches thick, which is compact, fine-grained, of bluish color, weathering to a buff. It is composed of fine, quartz grains of sand similar to those of the Bedford or Sharpsville sandstones. On this bank this sandstone member has a thickness of 7 feet 8 inches, above which is a foot of soft, argillaceous shale of the Brecksville. This sandstone zone is also shown in the run from the north, entering the creek a short distance below the last ledge of the upper layer of the Berea grit, on the same side of the creek. In this run there are loose blocks, apparently of this sandstone, which show ripple-marks, and the member is about 8 feet in thickness. Argillaceous shale, bluish to buff colored as weathered, occurs in the run above this sandstone. The shale interval between this sandstone and the Berea grit is twice or three times as thick as between the Berea and the sandstone in the Cleveland region. On this account the writer isnot sure that they are identical, and for convenience in referring to this higher sandstone the name Chardon is proposed for it from this locality in the western part of Chardon Township	7	8	274—
13.	Shale zone; the lower portion of which at least represents the *Sunbury shale*. The upper part of this zone is shown on the northern bank of the main creek, not far below the sandstone cliff which was described above. This portion of the shale is bluish to blackish in color, soft and argillaceous, with an occasional sandy, bluish layer, one-fourth of an inch or so in thickness. In the summer of 1909 the northern bank above the ledge formed by the upper layer of the Berea was uncovered so that the shale for 17 feet was exposed in an almost vertical cliff, above the top of the Berea sandstone. This cliff was measured by Mr. Morse, who obtained the following section: Bluish, argillaceous shale, which is rather indurated in the upper part of the exposure, 11 feet. Band of black, tough shale, with bluish, softer shale			

No.		Thickness. Ft.	Thickness. In.	Total thickness. Feet.
	below. Underneath is bluish-black shale, and the basal part is black, bituminous, and very tough, with the lithologic characters of the Sunbury shale, which rests directly on top of the Berea sandstone, 6 feet. Farther up the stream, where the shale is exposed on its bank, and in its bed, the black shale is again shown resting directly on top of the Berea sandstone, and within 1 or 2 inches of the Berea it contains specimens of *Lingula melie* Hall in considerable abundance and also of *Orbiculoidea herzeri* Hall and Clarke, which are the abundant species almost universally found within 2 or 3 inches of the base of the Sunbury. The thickness of this shale interval was obtained in the run from the north, which enters the main creek a short distance below the cliff, formed by the upper layer of the Berea grit. In this run the top of the Berea is shown, as well as the base and entire thickness of the superjacent sandstone (Chardon). In the run nearly 1 foot of blue argillaceous shale is shown just beneath the Chardon sandstone. The thickness of the shale interval is 29 feet as determined by Mr. Morse, from leveling, and the barometer gave 30 feet for it	29	--	266
12.	Top of *Berea sandstone*. Upper zone of massive sandstone. The top of the Berea sandstone, where shown in the creek bed, with the Sunbury shale above, and also farther down the stream where the upper zone forms a ledge on its bank, is pitted and rough, evidently from the disintegration of iron pyrites, as is very generally the condition of the upper surface of the Berea. This upper, massive zone is composed of coarse, white quartz grains, and in the upper layer grains of iron pyrites are mingled with them. It is buff in color and rusty as weathered, so that the texture is that of the Berea sandstone and not at all like that of the Chardon sandstone. In a small gully on the northern side, just below where it forms a cliff on that bank, the upper surface shows ripple-marks. The hardness and lithologic appearance of this sand-			

No.		Thickness. Ft.	In.	Total thickness. Feet.
	stone zone in this glen is very similar to that of the upper sandstone zone of the Berea formation, to be described, in a branch of Bates Creek and at Windsor Mills. In all of these outcrops the grains of sand are generally firmly cemented together, so that it is not friable like the main mass of the Berea	4	6	237
11.	Shale zone composed of bluish-gray, argillaceous and arenaceous shales, alternating with bluish, fine-grained, compact sandstones an inch or less in thickness, in which the arenaceous shale predominates. Some of the layers show fine ripple-marks, while on the top of others are numerous fucoid markings. Most of the shale is very gritty and not at all like the Sunbury in lithologic character, so that there is no question concerning its occurrence in the Berea formation. The base of this zone begins above the cascade, and by the hand-level is 8 feet in thickness. It closely resembles lithologically the shale zone, described farther on, which occurs in the upper part of the Berea formation at Windsor Mills. The corresponding shale zone, in the upper part of the Berea formation, in a branch of Bates Creek, which will be described later, is to a much greater extent an argillaceous shale	8	--	232½
10.	Main mass of Berea sandstone, the top of which, by taking the average of two readings of the barometer, is 56⅔ feet higher than its base. The upper part of this zone, above the upper cascade, is thin-bedded, flaggy, and shows some ripple-marks. The narrow part of the "gulf" or canyon has been excavated out of this portion of the formation, and is located on the Hitchcock and Barnes farm, which was formerly the Stebbins farm. Near the upper part of this zone is a cascade, while the sandstones at the base of the formation give rise to a fall of about 10 feet in height. Between these two cascades most of the gorge is comparatively narrow, and bounded by steep sides of massive sandstone. The lowest bed, which occurs at the top of the lower fall, is 1 foot 4 inches thick, composed of coarse, quartz sand, and			

No.		Thickness. Ft.	In.	Total thickness. Feet.
	splits into rather thin layers, which show ripple-marks and mud-cracks. The chemical composition of the base of this bed is as follows, according to the analysis by Professor Demorest: Clay, 13.8%; quartz, 74.5%, feldspathic material, 10.7%; Fe_2O_3, 1%. Just above the fall, small pot holes occur in the bed of the creek. Above the lowest stratum is massive sandstone, forming high cliffs. The one on the northern bank, above the lower fall, shows a zone of very heavy and conspicuous cross-bedding, about 7 feet above the base of the formation, which overhangs the fall and stream. This massive part of the Berea is of buff color and the grains of sand not very firmly cemented, so that it disintegrates readily, forming beds of loose sand on the talus slopes. On the northern bank, heavy beds of Berea sandstone may be followed for some rods down the stream from the fall, and at the lower end, where conspicuous, the base is some 45 feet or more higher than the bed of the stream. Opposite, and below the picnic grounds, this part of the ledge is well shown, where from near its top a large grindstone has been partly fashioned. According to the barometer, 50 feet of Berea sandstone is shown at this locality in the ledge which in the upper and middle part is buff to yellowish-brown in color, coarse-grained and friable, so that on a weathered surface it is rather easily crushed in the fingers. Near the base of the massive cliff the sandstone is soft, buff in color, with numerous brownish spots, and there is cross-bedded structure. The complete thickness of the formation, as determined partly by barometer and partly by level, when followed from the lower fall up stream to the top of the ledge formed by the massive upper zone, is 69⅓ feet, which, at least from the standpoint of thickness, makes this an important section of the Berea sandstone in northern Ohio------	56	8	224½
9.	*Bedford formation.* At its top, as shown in the lower fall, is a stratum of soft, blue, argillaceous shale, the top of which is regarded as marking the upper limit			

No.		Thickness. Ft.	In.	Total thickness. Feet.
	of the formation. This zone, as shown on the eastern bank of the creek, about 100 yards below the fall, has decreased in thickness so that it varies from a little more than an inch to rather more than 2 inches, and the coarse Berea sandstone rests almost on top of the subjacent thick-bedded, fine-grained, blue, Bedford sandstone. From the fall, as this shale zone is followed along the bank, its rapid thinning from above is very clearly shown, indicating that it is due to erosion previous to the deposition of the coarse Berea sands. This thinning of the shale zone brings the Berea and Bedford sandstones almost into contact on the cliff; but their weathered appearance is quite different, the Berea showing that it is coarser grained and not so compact as the lower, blue sandstone. The overhanging, lower surface of the Berea shows large and beautiful casts of mud-cracks, and there are also some clay pebbles in the lower part of the Berea. The lower portion of the Berea here has thickened to a massive sandstone from the thin-bedded sandstone shown in the falls above. This bank seems clearly to show a disconformity between the Berea and Bedford formations. On the bank the marked break is at the base of the $8\frac{1}{2}$-inch blue sandstone, zone 6, and at first this horizon was considered as the line of division between the Bedford and Berea formations; but the facts stated above show that the line of separation between these two formations is at the base of zone 10	1	--	$167\frac{5}{6}$
8.	A stratum of compact, blue sandstone, composed of fine, quartz grains, so that it is largely a quartz sandstone; but lithologically like those found at other localities farther east in the upper part of the Bedford. The analysis by Professor Demorest showed its chemical composition to be as follows: Clay, 12.7%; quartz, 70.2%; feldspathic material, 15.5%; Fe_2O_3, 1.6%	1	10	$166\frac{5}{6}$
7.	Blue, argillaceous and arenaceous shale	--	$3\frac{1}{2}$	165
6.	Blue, fine-grained, quartz sandstone, with tendency to split into two or three layers	--	$8\frac{1}{2}$	$164\frac{2}{3}$+

No.		Thickness Ft.	In.	Total thickness. Feet.
5.	Blue shale, with thin sandstone layers to the foot of the fall	7	6	164
4.	Shales alternating with bluish, fine-grained compact sandstones, one layer of which reaches a thickness of between 10 and 11 inches. The top of the thin sandstone layers shows numerous fucoid markings, and one shows ripple-marks. In this part of the formation the sandstones form a large percentage of its total thickness. The lower part of the Bedford is mostly covered by talus, so that it is not a favorable locality to hunt for the fauna which occurs in the basal layers of this formation. There are some sandstone layers shown in the bed of the stream not far above the base of this formation, and an occasional sandstone layer is a foot or so in thickness. Its base is apparently marked by a sandstone about 1 inch thick. The barometer gave 45 feet for its thickness and 48 feet was obtained by leveling. Read gave the thickness of this formation in Geauga County as "from forty to fifty feet."[1]	40	6	156½
3.	*Cleveland shale.* The contact is not so sharp in this glen as in some sections. On the northern bank of the main stream, below the 1-inch sandstone mentioned, at the base of the Bedford, there is black, alternating with blackish to bluish-gray, shale. This zone is perhaps about 5 feet in thickness, and it was found that the shale with a bluish-gray surface is considerably blacker on cross section when broken. In fact, it is apparently mainly black shale to the thin sandstone, and hence this zone has been left in the Cleveland shale. Farther down the stream, the lower part of the Cleveland is shown, which is very black and compact like this shale in the Cleveland region. The contact with the Chagrin formation is very sharp, and is well shown on both the northern and southern banks at no considerable distance apart. On the southern bank, at the farthest contact up stream, occurs a steep bank in which there is 3 feet of Chagrin shale at the base, to the bed of the stream,			

[1]Ibid., p. 525.

No.		Thickness. Ft.	In.	Total thickness. Feet.
	with about 10 feet of very black Cleveland shale above. The slope above the vertical cliff is also steep, showing black shale considerably higher, the upper layers of which are apparently very black, and some of this shale contains a considerable quantity of marcasite. Nearly 27 feet of Cleveland shale was obtained by the level on this bank, while the barometer gave 20 feet between the top and bottom on the main stream. Read estimated in the report on Geauga County, that the "ravines cut through about forty feet of the Black or Cleveland shales."[1] The next bank below, on the opposite side of the stream, shows a sharp and very clear line of contact, with about 7½ feet of bluish-gray, Chagrin shales below, which are coarse at the base, and rest on top of a sandstone. This sandstone, a little farther down the stream, makes a fall, while there is about the same thickness of Cleveland shale shown above the contact as of Chagrin below it	26+	--	116
2.	*Chagrin formation.* There are practically continuous outcrops of the upper 30 feet of this formation, as measured by the barometer, which extend to below the mouth of "the Gulf." The rocks consist of soft, bluish-gray shales, with some that are sandy, and occasional thin, rather shaly layers of sandstone, which form low falls. No fossils were found with the exception of certain branching forms of a rather small and pretty fucoid, which is abundant, and well shown in one of the thin, impure sandstones	30	--	90
1.	The greater part of this interval is covered, showing only alluvial deposits, with a bank of boulder clay, and stratified, sandy drift only a few rods above the river road. There are, however, outcrops of Chagrin shale, just above the abutment of the highway bridge, and only 2 or 3 rods from the mouth of the creek, as well as on the banks of the East Branch of the Chagrin River, near its mouth. This interval is 60 feet by the barometer; but the reading was taken			

[1]Ibid., p. 525.

No.		Thickness. Ft.	In.	Total thickness. Feet.
	when a thunder storm was in the vicinity. It probably, however, is not seriously in error, for Read, in the Geauga County report, states that "the branches of Chagrin River, in Chardon, expose something over one hundred feet of the Erie shales, the lowest rocks to be seen in the county."[1]	60	--	60

The following section was measured on the bank of the creek about 100 yards below the fall over the base of the Berea sandstone, where the top shale stratum of the Bedford formation has thinned from 1 foot to a little more than an inch or two in thickness.

Section 100 Yards Below Falls.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
7.	*Berĕa sandstone.* Coarse-grained and massive. The overhanging lower surface shows large and beautiful casts of mud-cracks	--	--	--	--
6.	*Bedford formation.* Blue, argillaceous shale, varying in thickness from 1+ inch to 2+ inches	--	1½±	15	4
5.	One layer of blue, compact sandstone	1	3	15	2½
4.	Blue, argillaceous shale	--	3	13	11½
3.	Blue, compact sandstone	--	8	13	8½
2.	Shale with thin layers of sandstone from a fraction of an inch to two inches in thickness	12	9	13	½
1.	Compact, blue sandstone in bed of creek	--	3½	--	3½

The different formations and zones shown on this stream may be represented in the following diagrammatic section:

[1]Ibid., pp. 525, 526.

General Section of Formations in Stebbins Gulch.

306′			
	32′	Brecksville shale	Orangeville formation (in part)
274 - ′			
	$7\frac{2}{3}$′	Chardon sandstone	
266′			
	29′	Shale zone Lower part equals Sunbury shale	
237′			
	$4\frac{1}{2}$′	Upper sandstone zone	Berea formation. Thickness $69\frac{1}{6}$ feet
	8′	Shale zone	
	$56\frac{2}{3}$′	Main mass of Berea sandstone	
$167\frac{5}{6}$′			
	$51\frac{5}{6}$′	Bedford formation	
116′			
	26′	Cleveland shale	
90′			
	30′	Continuous outcrops shale and thin sandstone	Upper part of Chagrin formation
60′			
	60′	Covered interval	
0′		Shale at base Level of East Branch	

It will be recalled that the base of the Sharon conglomerate has been described on the highway below the house of Mr. Austin Hayden not far northwest of Chardon Centre. The top of the Berea sandstone in Stebbins Gulch is about 1 mile southwest from the basal outcrop of the Sharon conglomerate above described. The thickness of the interval from the base of the Sharon conglomerate to the top of the Berea sandstone at this locality was determined by the barometer from two readings which gave on each occasion 180 feet. It is believed that 180 feet is a fairly accurate estimate for the thickness of the Cuyahoga terrane at this locality, which is also in agreement with the statement of Read in his report on Geauga County that the "Berea grit is to be found at an average depth of one hundred and eighty feet below the conglomerate."[1]

Gloin Gulch.—Rather more than three miles to the west of south of Stebbins Gulch in the northwestern corner of Munson Township is Gloin Gulch, also on another eastern tributary of the East Branch of the Chagrin River. The gulch is located on the Fred Haverly farm, the steepest part of it bounded by cliffs of Berea sandstone which was formerly quarried by John Gloin, a contractor, and the stone was used

[1]Ibid., p. 523.

in the basement of the Chardon Court House and the Methodist Episcopal Church. Almost directly opposite and northeast of the Haverly farm buildings, is a fine hogback between the forks of the stream and on its steep southern slope the upper part of the following section is shown. For a few rods below the junction of the two branches of the stream there is a moderately broad valley with gradually rising banks, the rocks of which are covered by soil and grass. Below this part of the valley, where the stream cuts through the Berea sandstone, it is narrow and bordered by steep cliffs forming the gorge or gulch.

Section of Gloin Gulch.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Brecksville shale.* About 7 feet of bluish-gray, as weathered, soft shale, with an occasional thin, sandy layer a fraction of an inch in thickness. Above is soil or Quaternary deposit to the top of the hogback	7	88⅔
4.	*Chardon sandstone.* Fine-grained, bluish sandstone, in layers varying from 6 inches to a foot in thickness, with partings of bluish, arenaceous shale, from 2 to 3 inches thick	9⅔	81⅔
3.	Black to bluish-gray, fissile shale fairly well shown on southern side of hogback. From the shale in the bed of the stream, to the base of the Chardon sandstone, is 20 feet by barometer and 22 feet by level. A slope of shale is also shown on the northern bank of the stream below the farm bridge, where the shale is very black in color. Lower part of this zone is probably equivalent to part of the Sunbury shale	22	72
2.	Covered interval from upper outcrop of Berea sandstone to exposure of shale in stream at foot of the hogback. It is probable that this interval represents part of the Sunbury shale. This shale zone appears to have about the same thickness as in Stebbins Gulch, 3 miles to the north, where it is 29 feet, while here it is from 22 to 27 feet thick	5	50
1.	*Berea sandstone.* The stream forms a cascade over the upper layers of the sandstone and several rods farther down its course the banks are steep, forming a gorge, where the rock was formerly quarried on both banks. On the northeast side, the base of the exposed, massive sandstone is about 30 feet below the top of the formation, where 7 feet 9 inches of massive, buff, coarse-grained sandstone is now shown. It is composed of white quartz grains, and in the lower part of the quarry are a good many brown rust spots. In places, the second layer from the bottom is 4½ feet in thickness, and would furnish thick blocks of stone for construction or building. Above the quarry, in the cliff, fully as great a thickness of higher rock is shown, part of which		

No.		Thickness. Feet.	Total thickness. Feet.
	is rather thin-bedded and the other is fairly massive. The thinner-bedded layers not infrequently show ripple-marks, and a little farther down the stream, this upper part is composed entirely of thin layers, with some cross-bedding. On the southwestern bank was apparently the more extensive quarry, and all of it is composed of fairly thick-bedded layers, with some shaly sandstone partings. From the base to the top of this quarry and cliff is 22 feet by level. Below the heavy quarry layers, and some rods farther down the stream, in its bed, are some thin-bedded layers; but all composed of the coarse, white, quartz grains characteristic of the Berea. A thickness of about 15 feet was obtained for this lowest division of thin-bedded sandstones, and below these thin layers the valley soon broadens, and the banks are alluvial	45	45

East Branch of the Chagrin River Near North Munson.—The top of the exposed Sharon conglomerate is shown on the bank of the East Branch of the Chagrin River just above the stone culvert on the highway and north of H. J. Scott's house in North Munson. Under the culvert and just below is a cascade as the stream flows over the upper part of the conglomerate. From the top of the ledge above the culvert to the base of the cascade is 25 feet by the barometer. Some of the rock contains many pebbles of white quartz and other portions are mainly a coarse sandstone to grit. In the lower part of the cascade near the base of the exposure are some large quartz pebbles. A good illustration of joint structure is shown on the southern side of the stream and culvert. So far as noticed the stream above the culvert and upper ledge has low alluvial banks and is said to head at the Magnetic Spring west of Chardon.

There is a covered interval for some distance from the cascade down the stream until 30 feet by barometer below the base of the cascade the first outcrop of the Cuyahoga terrane is reached with a thickness of about 10 feet. It is composed of shales alternating with thin sandstones, the layers of which vary in thickness from 3 to 4 inches. The shale is bluish in color and composed of rather thin laminæ. A short distance farther down the stream is a better exposure of shale and rather higher bank which shows that most of the outcrop is composed of bluish-gray, soft shales weathering to a rusty color with some thin layers of sandstone, none of which, however, is probably more than 3 inches in thickness. Rather more than 15 feet below the top of the first outcrop a stratum of bluish, fine-grained sandstone between 4 and 5 inches in thickness appears in the bed of the stream. Farther down the branch bluish-gray shale occurs below this sandstone, where there is a bank about 15 feet high composed mainly of soft shale, and another exposure

still farther down the stream of soft shale which is bluish-gray to drab on exposed surface but nearly black on a fresh fracture. On the southern bank of the branch, just below where a run enters on the same side, is a large block of Sharon conglomerate, containing near its lower end large quartz pebbles, which has moved down the hill or stream, and just below is a high bank of boulder clay. The East Branch was followed for about one and one-third miles below the cascade down through the woods and somewhat narrow valley until the open fields were reached where the valley broadens. The lowest outcrop seen was a stratum of sandstone several inches in thickness in the bed of the stream. After the highest outcrop of the Cuyahoga is reached the shales and thin sandstones of this terrane are more or less completely shown along the banks of the stream as far as it was followed.

In a gully about north of where the East Branch was left, below the house of Charles Page, and barometrically 110 feet above the bed of East Branch, a coarse-grained sandstone was reached. Somewhat farther up the run and barometrically 30 feet higher are ledges containing large pebbles, so that this rock evidently belongs in the Sharon conglomerate. The barometer was read twice at the top of this ledge and at the top of the one above the culvert in North Munson with an interval of about twenty-five minutes between the readings in each case, giving in one instance a difference of elevation of 60 feet and in the other of 65 feet. The ledge above the stone culvert is about 1.1 miles north of east of the former locality and these readings indicate that in this region the Sharon conglomerate has a thickness of at least 90 or 95 feet.

The Sharon conglomerate in the gully below the Page house is about three-fourths of a mile southeast of the Berea sandstone in the Gloin Gulch. The day this locality was studied the barometer was falling so that the estimates are somewhat less than the actual difference in altitude. The barometer with an interval of thirty-five minutes between readings gave a difference of 100+ feet between the top of the Berea sandstone in the Gloin Gulch and the base of the exposed conglomerate in the gully below the Page house. This interval represents the entire Cuyahoga terrane and seems to indicate that in this locality its thickness is not much greater than 100 feet. From the top of the Berea sandstone in Stebbins Gulch to the base of the Sharon conglomerate near Chardon Centre, three and two-thirds miles northeast of the Gloin Gulch, 180 feet was obtained for the thickness of the Cuyahoga terrane. This apparently shows a rapid decrease in thickness of the Cuyahoga between the two localities which is probably due to a greater amount of erosion in the Gloin Gulch region before the deposition of the Sharon conglomerate, than occurred in the Chardon Centre region. These two localities apparently furnish additional proof of the belief that the Sharon conglomerate was deposited on a very uneven surface of the Cuyahoga terrane.

Little Mountain Sections.—About one mile east of north of Mitchells Mill, where the East Branch of the Chagrin River turns from a northerly to a westerly course, or three and one-half miles southeast of Mentor, is a high and conspicuous hill known as Little Mountain. Its elevation is about 1,270 feet above sea level and it is a marked topographic feature when approached from the north. To the south of the "mountain" the country is higher and much more broken than it is to the north so that the "mountain" is not nearly so conspicuous a landmark when seen from the south.

Weller Creek, which has already been described, may be reached at a distance of about one-half mile from the southern end of the "mountain" and although part of the slope is rather steep, still it appears to be mantled by soil and drift until well toward its top. In the fields are numerous boulders of crystalline rocks, relics of glacial time; but outcrops of Paleozoic rocks were not found in the runs south of the east and west highway crossing the southern slope of the "mountain." Mr. Read stated that the Berea grit "is quarried on Chardon Road about half a mile south" of the main approach to the "mountain;"[1] but the writer failed to find this outcrop. He also talked with an intelligent farmer—Mr. Phelps—who has lived in the vicinity sixty years and he knew of no quarry to the south of the "mountain" that was ever opened in the Berea grit or of outcrops of rocks between the east and west road and Weller Creek.

Above the east and west highway on the Griswold farm and near the southeastern angle of Little Mountain is a fair ledge of the Sharon conglomerate perhaps in some places 20 feet high. The sides of the cliff show numerous excellent examples of cross-bedding and considerable differential weathering. Part of it is rather pebbly; although not nearly to so great an extent as in the ledges near the hotel at the northern end of the "mountain." At one point a fine spring emerges from beneath the conglomerate. The difference in elevation from the top of the cascade in Weller Creek on the Knierim farm to the base of the exposed conglomerate on the Griswold farm according to the barometer, with an interval of about one hour between readings, is 270 feet. The distance between these two localities is about one mile along a nearly north and south line while the interval includes the Cleveland shale, Bedford formation and Cuyahoga terrane. It is to be remembered that on the road southeast from the cascade in Weller Creek toward Chardon Centre with a distance of 1.4 miles between the two localities a thickness of 325 feet, or 55 feet more, was obtained for the same interval.

On the Chardon Road to the west of Little Mountain the Berea grit is shown a few rods southeast of the four corners at which the signboard says 6 miles to Chardon and 4 miles to Mentor. A short distance to the northeast of this four corners is another one at which there is a

[1]Geol. Surv. Ohio, Vol. I, 1873, p. 523.

store and where formerly the Little Mountain post office was located, while about the same distance to the west of this four corners and to the northwest of the one first mentioned, just below the school-house, is the third four corners. The Chardon road from the outcrop of Berea grit mentioned above was followed to the northwest past the first and third four corners mentioned above and in the same direction beyond a fourth four corners the altitude of which is marked on the Mentor quadrangle as 802 feet. For a distance of nearly one mile on this road to the northwest of the outcrop of Berea grit, the rocks are shown to some extent in the gutters beside the road and the following section was measured. For want of a better or more definite local name this highway will be called the Chardon road.

Section on Chardon Road Northwest of Little Mountain.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Berea grit.* The top of the exposure is shown on the highway a few rods to the southeast of the first four corners mentioned above; but it is not the top of the formation. The upper portion of the exposure is a coarse-grained sandstone or grit, composed of white, quartz grains; with rust spots from iron weathering, like the stone in the Curtis quarry farther to the east on the Chardon-Concord road, which will be described later in this bulletin. For some distance toward the "mountain" the rise is very gradual, and this comparatively level area is underlain and supported by the Berea grit. It continues beyond the first four corners toward the northwest, and the base is apparently shown in the road a little above the watering trough. The roads about the corners are very sandy from the cut up and disintegrated Berea grit. From the lowest layer on the road above the watering trough to the top of the outcrop, was twice given as 15 feet by the barometer, and made 16 feet by the hand-level	16	216
4.	*Bedford formation.* From the watering trough to the next four corners (at crossing of the Mentor-Little Mountain road), the rocks are mostly covered, with an occasional exposure in the gutter of thin sandstones, which are rather olive in color on the surface, but more nearly buff when broken. Below the four corners, the exposures of thin sandstones are more frequent, together with indications of soft, argillaceous, olive shale. On the Mentor-Little Mountain road, above the four corners and school-house are thin sandstones, alternating with shales, before reaching the Berea grit. The contact of the Bedford formation and the Cleveland shale is not shown, but the average of three readings of the barometer for the interval from the top of the highest outcrop of the Cleveland shale to the ledge of Berea		

No.		Thickness. Feet.	Total thickness. Feet.
	grit above the watering trough was 75 feet. This interval may be somewhat greater than that of the Bedford formation, since it may include some of the Berea grit at its top, and some of the Cleveland shale at its base	75	200
3.	*Cleveland shale.* Two feet or more of black, Cleveland shale is shown in the gutter by the side of the road, several rods above the house of Clayton Booth. Occasional exposures occur by the side of the road until a short distance north of W. M. Neill's house. The thickness of 20 feet was obtained from a single reading of the barometer. Mr. Neill told the writer that in a well at his house on the eastern side of the road, they passed through 4 or 5 feet of the Cleveland black shale, and then went down into soapstone. In a well on the opposite side of the road, and on a little higher ground, from 8 to 10 feet of black shale was penetrated before reaching the soapstone. In the banks of gullies to the east of the house of Clayton Booth, and the upper exposures by the side of the highway, are outcrops of black Cleveland shale. These banks are sloping, and the loose shale covers them; but one shows perhaps 15 feet of the shale in place. The contact at either the top or bottom of the shale is not shown. One reading of the barometer gave the lowest outcrops of the Cleveland shale in the highway gutter at this locality as 345 feet higher than the Grand River, below the Abbot mill and river bridge at Painesville	20	125
2.	*Chagrin formation.* The top of the formation is reached in the roadside a short distance below Mr. Neill's house. The upper part of the formation, as shown from the partial exposures, consists of soft, bluish and greenish, argillaceous shales. Farther down the road, and of course stratigraphically lower, shales and grayish, shaly sandstones, which weather to a very rusty color, due to iron which they contain, are shown in the gutter. According to one barometric reading, the upper 35 feet of the Chagrin formation is partly exposed	35	105
1.	Drift or soil is shown in the banks and gutters of the road from the lowest exposure of the Chagrin formation for 70 feet to the next four corners, which is marked 802 feet above sea level on the Mentor topographic sheet. Beyond this last four corners, toward the north, the slope is very gradual, with few, if any, exposures of the Paleozoic rocks	70	70

At the northern end of Little Mountain is a rock cliff below which is a steep slope and the view from the top of this cliff toward the north is one of great beauty, with the upper wooded slope, the fields and woods

below and Lake Erie in the extreme distance, which once seen and appreciated remains in the mind of the beholder for a long time. This northern part of the "mountain" is still largely covered with tall pine trees, except near the northern edge where they have been cut away for buildings and to afford an unobstructed view from the Pine Crest Hotel. For a number of years this was an excellent summer hotel in connection with which was a considerable number of cottages located in picturesque spots and the place had a desirable reputation as a summer resort. For several years, however, the hotel and cottages have been unoccupied and are now falling into decay. It is certainly an attractive place for such a resort and one of the most picturesque spots that the writer has seen in Ohio.

The "mountain" is capped by the Sharon conglomerate which is well shown in cliffs and in joints where the rocks have separated sufficiently so that there are passageways between the blocks. A number of excellent exposures of this sort occur in the rear of the hotel, where in one place near the Devil's Kitchen the walls are 26 feet high, and also near the road where a number of cottages have been built. The conglomerate is well shown on the road leading up the steep slope of the "mountain" to the Pine Crest Hotel and to the south of the road because of its natural jointing. Much of the rock is a coarse conglomerate containing large pebbles which are mainly white quartz. A close view of a portion of one of these ledges near the roadway is shown in Plate LV, B, in which the white quartz pebbles are distinctly seen, many of them projecting slightly from the face of the cliff. The layers of very coarse conglomerate (with large quartz pebbles) do not extend far; but are frequently cut off obliquely by channel fillings. There is also frequent cross-bedding and this structure together with that of channel filling are both excellently shown. It all admirably exhibits the structure which might be expected on an old shore line where coarse deposits were being thrown down. At the "outlook" in front of the hotel the cliff of conglomerate is 22 feet high and a little farther to the east it is 27 feet high. In the rear of the hotel excellent jointing of the conglomerate is to be seen where the "rock city" structure has been formed. At one place the large roots of a tree are conspicuously shown on one face of the ledge where they had grown in a joint and helped to push the blocks of conglomerate apart.

From the summit of the "mountain" at Pine Crest Hotel the rocks are fairly well shown for part of the distance for a mile or more along the private road down the hill and the Little Mountain-Mentor highway to the westward. A section has been prepared from the highest outcrops of the Sharon conglomerate at the hotel to the base of the Berea grit on the Little Mountain-Mentor highway.

Section from Little Mountain down the Mentor Highway.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Sharon conglomerate.* According to the barometer, the outlook to the northwest of Pine Crest Hotel is 10 feet lower than the outcrop just in front of the hotel, while to the base of the ledges shown on the road is 40 feet lower than the outlook, according to two readings of the barometer. It is thought that the base of these large blocks is not far from the base of the conglomerate, although it is probable that they have crept down the steep slope to some extent. A reading of the barometer in the summer of 1909, gave 70 feet from the base of the large blocks on the road to the top of the outcrops in front of the hotel. The U. S. Geol. Survey bench mark on the front of the hotel, and near its foundation, is 1,244.29 feet above sea level	50+	287
3.	Covered interval. From the base of the ledge of Sharon conglomerate to the highest outcrop of Berea grit, just below the house of Rev. Wm. Reynolds, on the Mentor highway. So far as observed, no outcrops occur in this interval, which covers the lower part of the abrupt slope of the "mountain" and its lower gradual slope for some distance, and represents in general the position of the Cuyahoga terrane, although probably including some of the upper part of the Berea formation. The average of two readings of the barometer, with an interval of 15 minutes between them in each instance, gave a thickness of 127 feet for this division	127	237
2.	*Berea grit.* The top of the exposed Berea, which is shown in the highway gutter just below the house of Rev. Wm. Reynolds, is strongly cross-bedded. To the northwest of the Basket factory is a ledge of the Berea, which by hand-level is 19+ feet, and by barometer 20 feet lower than the top exposure below the Reynolds house. From this latter locality are somewhat frequent exposures in the highway gutters to the Little Mountain store and former postoffice at the four corners. Cross-bedding is also shown in a coarse-grained rock in the gutters above the store. By level it is 14 feet from the outcrop northwest of the factory down to the top of the rather conspicuous, coarse-grained layer in the road at this four corners. This layer forms a rather noticeable terrace, with comparatively level ground for some little distance, extending southeasterly to the four corners on the Chardon highway, and is apparently at the base of the formation, since the lower sandstones are finer grained and lithologically like those of the Bedford. This section gives 160 feet for the thickness of the Berea grit and Cuyahoga terrane, or the interval from the base of the Berea grit to the base of the blocks of Sharon conglomerate, while a later reading of the barometer gave 155 feet for the same interval	33	110

A.—Cliff of the Chagrin formation on Chagrin River one mile below Pleasant Valley. See page 504.

B.—Near view of Sharon conglomerate on Little Mountain showing the white quartz pebbles. See page 557.

No.		Thickness. Feet.	Total thickness. Feet.
1.	*Bedford formation.* Below the sandstone just mentioned, at the four corners, the rocks are mostly covered, and it is hardly possible to say positively that the base of the Berea is not somewhat lower; but the geologic evidence at hand seems to show that it is not. Just above the church, however, and shown to best advantage in the gutter on the opposite side of the highway, is a ledge of buff, rather coarse-grained sandstone, which splits into thin layers one-half inch or more in thickness as it weathers. The base of this layer by hand-level is 28 feet lower than the conspicuous one at the four corners above. Below is a concealed interval for 9 feet, when a ledge of rather fine-grained, grayish sandstone with one 4-inch layer is reached. This sandstone is composed largely of fine, white, quartz sand and the ledge is shown in the highway gutter on the northern side of the road, not far below the church, and at a greater distance above the school-house. Below this sandstone ledge are gray, arenaceous shales to soft ones, which lithologically resemble those of the Bedford, and also thin sandstones. The barometer gave 49 feet from the base of the sandstone described, just above the church, to the upper exposure of Cleveland shale on the Chardon road above the house of Clayton Booth. This gives 77 feet for the interval, which is referred to the Bedford formation, although it does not follow that all of it belongs in this formation, since, at the top, the interval may include some of the lower part of the Berea, and, at the base, some of the upper part of the Cleveland	77	77

Since the above account was written this locality has been reëxamined in company with Mr. Wm. C. Morse and it was noted that the sandstones in the road gutters below the Little Mountain store down past the church and school-house are all composed of fine-grained quartz sandstone, more or less iron-stained; but much firmer than the Berea and not friable. The ledge at the store corners and above the watering trough on the other road appears to be at about the base of the Berea formation and at about the same level according to the barometer. The thin, fine-grained quartz sandstones in the Bedford occur as shown in the road gutters nearly down to the Cleveland shale. Not over 5 feet of the basal part of the Bedford is covered and in the overlying beds the thin, fine-grained quartz sandstones with compact structure occur. This seems to show conclusively that the fine-grained sandstones opposite the church and farther up the road belong in the Bedford and not the Berea formation. One reading of the barometer gave from the Berea sandstone at the store corners down to the highest exposed black Cleveland shale 65 feet for the interval which is approxi-

mately that of the Bedford formation while another reading gave nearly 70 feet.

The thickness of the formations in the above sections near Little Mountain compares as follows with those obtained 2.3 miles farther southeast in Stebbins Gulch and toward Chardon Centre: The Cleveland shale is 26 feet in Stebbins Gulch while at least 20 feet occurs near Little Mountain; Bedford formation is 48 feet in Stebbins Gulch and apparently it is in the neighborhood of 70 feet near Little Mountain; Berea formation 69+ feet in Stebbins Gulch and at least 33 feet on the Little Mountain-Mentor road; Cuyahoga terrane from Stebbins Gulch to Chardon Centre is 180 feet and on the covered slope of Little Mountain there is toward 127 feet; while 30 feet of the Sharon conglomerate is shown near Chardon Centre and 50 feet or more on Little Mountain.

On the Painesville road, to the northeast of the store and four corners, the Cleveland black shale appears along the side of the highway and in the gutter some distance below the house of Mr. Morley and a road turning to the east and a short distance above a small run. Higher, but still below the house, the Bedford shale is shown for some little distance in the road gutter.

The rocks are fairly well exposed along the north and south highway past the Hermitage just northeast of "the Knob" or rather more than one-half mile northeast of Little Mountain. The Berea grit is also apparently shown on this same highway to the southeast of "the Knob" where a coarse-grained friable sandstone occurs in the gutter; but on that side of "the Knob" there are very few outcrops. On the opposite side the rocks are much better exposed and the following section along the highway was constructed:

Section along North and South Highway to the Northeast of "The Knob" and Little Mountain.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Orangeville formation.* Soft, bluish-gray shales, decomposing to clay, by the roadside. These shales begin a little below the three corners where a crossroad runs directly west and continue, according to the barometer, for 15 feet, when apparently only soil is to be found by the roadside	15	145
4.	*Berea formation.* Thin ledge of brownish sandstone just below three corners, which is apparently the top of the Berea formation. Then for 20 feet the rocks are practically concealed, when fairly conspicuous sandstone exposures are reached. Between the middle and upper Hermitage houses in the road gutters, are thin-bedded, ripple-marked, buff, coarse-grained and friable sandstones, and by the barometer some 30 feet of these sandstones are shown	50	130

No.		Thick-ness. Feet.	Total thick-ness. Feet.
3.	*Bedford formation.* This interval is mainly covered, and the barometer makes its thickness 63 feet, the greater part of which belongs in the Bedford formation	63	80
2.	*Cleveland shale.* The shale is entirely black in color, and is well shown in the small hill on the road above the lower Hermitage house. The contact with the Chagrin shale is sharp, and well shown in the gutter on slope of ledge a little above the same house	17	17
1.	*Chagrin formation.* As stated above, the contact with the Cleveland shale is sharp, and clearly shown, and just below the black shale is soft, bluish-gray shale of the Chagrin formation. Opposite the lower Hermitage house are thin sandstones alternating with arenaceous shales, and rocks of this general structure are exposed in the gutter for some distance down the road; but the thickness was not measured.		

Prior to the fall of 1904 four wells for oil or gas had been drilled in the southern part of Concord Township on the Hermitage farm at an expense of between $10,000 and $11,000, all of which began in the upper part of the Chagrin formation. The mouth of well No. 1, according to the barometer, is 95 feet lower than the base of the Berea grit on the highway. Mr. G. H. Carroll reports that it was drilled in 1902 and is probably between 2,100 and 2,200 feet in depth and considerable gas was obtained; but only a little oil. The oil or gas is reported to come from a "sand" which is supposed to be in the upper part of the Monroe formation similar to those sandstones noted in the Cleveland wells and others in northeastern Ohio, which will be described later in this bulletin. Unfortunately the writer was unable to obtain a detailed log of any of these wells and consequently no very positive stratigraphic comparisons can be made between them and the wells in Cleveland or vicinity, or with those of any other locality.

Mr. F. C. Carroll reported that the top of the limestone was reached in this well at a depth of about 1,600 feet; rock salt at 1,950 feet with a thickness of perhaps 2 feet; brownish chips with oil at about 2,000 feet, and 50 feet deeper, gas. He gave the total depth of the well as 2,150 feet. In this record the interval of 400 feet from the top of the limestone to the oil-bearing horizon agrees closely with that of well No. 4 of the United Salt Company at Cleveland, where it is 390 feet from the top of the limestone to the white sandstone. The rock salt horizon at a depth of 350 feet below the top of the limestone is apparently a different and higher horizon than at Cleveland, since in well No. 4 of the United Salt Company it is 775 feet from the top of the limestone to the salt.

Mr. D. B. Duff, president of the Vandalia Gas Company, Cleve-

land, and a member of the firm of Duff Brothers and Bower, who drilled these wells, has kindly furnished the following information concerning this well: It was located about 1,800 feet from well No. 2 and about 50 feet higher. The formation was practically the same as in No. 2, with the exception that, though we found some sand at the same depth in the limestone as we did in No. 2, we only got a little show of oil and scarcely a show of gas; but 60 feet deeper we got a brown sand, quite porous, and a strong flow of gas at a total depth of 2,058 feet. We drilled an $8\frac{1}{4}$-inch hole to this depth and after the well was wide open for 30 days we tested it with a mercury gauge and it measured over 600,000 cubic feet of gas per day. We packed the well and used the gas in drilling others and it was free from water for about six months, when the salt water commenced to come in and drowned the gas out. We missed this sand and gas entirely in well No. 2. There is no question but that there are two horizons that produce oil and gas in these wells, and while the figures are not accurate to a foot, there is about 60 feet between the sand in which we found oil and gas in No. 2 and the sand in which we got the most gas in No. 1. In this well the drillers say they went through a little rock salt, perhaps 2 or 3 feet, between 1,900 and 2,000 feet.

Well No. 2, and the remaining ones, were drilled in 1903. Its mouth is in a gully to the north of No. 1 and 70 feet lower according to the barometer. In this gully just above the well the bluish-gray shales of the Chagrin formation are shown. This well furnished more oil and flowed for a longer time than any of the others. The oil is rather thin and of greenish color similar in general appearance to that from the Monroe formation in the wells east of Chardon and near Andover.

Mr. D. B. Duff has furnished the following information concerning well No. 2: Twenty-three feet of drive pipe shut off all clay and drift. Then there was a sort of sandy shale or sandy flag, but not real sand, to a depth of 150 feet. The first 457 feet of shale contained some fresh and some salt water, at the bottom of which we set the $6\frac{1}{4}$-inch casing. The shale continued to a depth of 1,580 feet, when limestone was struck. The rocks to this depth were all shales alternating blue, brown and sort of whitish color. There is no regularity, however, as to the color of the shale in this county; one well may be a different color than one located 500 feet from it; even at the same depth. From 1,580 to 1,950 feet was hard limestone, in some places a little gritty—the driller would call it a kind of sand. A hard sandstone—real sand—about 30 feet thick was found in the limestone from 1,950 to 1,980 feet. Oil, gas and salt water were obtained at a depth of 1,950 feet. The first day we bailed out 7 barrels of dark green oil which we believe was of the Pennsylvania grade. For several days the gas from this sand escaped to the extent of probably 200,000 cubic feet a day. We shot the well in this sand with about 200 quarts; but it did not appear to help the flow. The well

flowed in the neighborhood of 100 barrels of oil, or on an average of about 3 barrels a day for about 30 days. That was after we put in tubing and packer, then the salt water weakened the gas so it would not flow. Below the sand is limestone to the bottom of the well at a depth of 2,047 feet.

We put in 480 feet of casing to shut off water; but I think we did not need nearly so much; 200 feet would probably have been enough. Previous to tubing the well, in drilling to the depth of 2,047 feet, we struck a strong vein of salt water that filled up over a thousand feet in a day or so. We plugged this vein off.

In the above record in connection with the section along the highway the thickness of the interval from the base of the Berea grit to the top of the Devonian limestone is 1,745 feet, or deducting 80 feet, the combined thickness of the Bedford formation and Cleveland shale on the highway leaves 1,665 feet for the combined thickness of the Chagrin formation and Huron shale. The interval of 370 feet from the top of the Devonian limestone to the oil bearing sandstone agrees fairly well with the thickness of the interval noted in the Cleveland wells between the top of the Devonian limestone and the sandstone that is correlated provisionally with the Sylvania sandstone.

Well No. 3 is 1,500 feet south of No. 1 and about the same amount of gas was obtained as from No. 1, but no oil. Well No. 4 is about north of No. 1, a little lower than No. 2 and yielded only salt water.

Outcrops on Chardon-Concord and State Roads.—On or near the main highway from Chardon through Concord to Painesville are outcrops of rocks which are worthy of mention. The one of most general interest and commercial value is the ledge of Berea sandstone opened in the Theodore Curtis quarry, in Concord Township, about one-half mile from its southern boundary and 1.8 miles south of Concord Village. From this quarry there is a steep descent to the north to the level of Gordon Creek which, as estimated from the topographic map, is some 220 feet, while one reading of the barometer gave 230 feet and another with a longer interval between the readings gave 250 feet. On a considerable part of this slope Paleozoic rocks are shown either in the roadway, the gutters or on the banks so that a fair section may be constructed. The intervals of this section will be based on the readings of the barometer which gave 250 feet from the Curtis quarry to the level of Gordon Creek, and the section was reëxamined in the summer of 1909 and more carefully measured.

Section from Curtis Quarry to Gordon Creek.

No.		Thickness. Feet.	Total thickness. Feet.
12.	*Berea sandstone.* Theodore Curtis quarry, which is apparently near the top of the formation. This is		

No.		Thickness. Feet.	Total thickness. Feet.
	opened on the western side of the highway at the top of the steep slope, where the ledge is fairly well shown. The top of the sandstone is glaciated, a part of its surface being smooth, upon which are faint striæ running 10° west of south. At the time it was studied, 4½ feet of coarse-grained sandstone was shown above water in the quarry, which was apparently, if unaltered, of gray color. Most of the exposed rock, however, was of brownish to reddish color from iron staining, while considerable of the grayish rock was very much speckled, from brown spots of iron rust. The rock is apparently composed of white, moderately coarse, quartz sand, with enough iron to stain it badly on weathering, so that it resembles somewhat in color the Shenango sandstone of western Pennsylvania and eastern Ohio. The 4½ feet shown in the quarry is a massive layer, with scarcely any indication of a bedding plane. It apparently lies almost level, but with a slight dip to the southwest. Mr. Morse leveled the interval from the base of the Berea to its top, as shown on the highway, and obtained 68 feet for the thickness of the exposed Berea. The barometer gave 60 feet for the same interval; but there was three-fourths of an hour's time between the readings, with a rising barometer, so that it would give less than the actual thickness	4½	243
11.	Shown on the opposite side of the road from the quarry, and mainly in the road gutter, as in the case of the lower zones. Top of the exposure on the highway, which is at about the same level as the top of the quarry. Massive stone, but containing much iron, so that it is harder than the lower rock, and composed of coarse, quartz grains. Zone partly covered. Thickness 9½ feet from the base to the top, and deducting the 4½ feet shown in the quarry, it leaves 5 feet for this zone, which is probably below the quarry	5	238½
10.	Shaly zone, very gritty, but in thin layers	2	233½
9.	Covered interval	7	231½
8.	Upper part of this zone contains considerable iron, and is harder than the lower rock. In general, the zone is composed of a friable, coarse-grained, white, quartz sandstone spotted with brown. Part of the zone is coarser bedded than the one below, and there is conspicuous cross-bedding	8½	224½
7.	Rather thin-bedded sandstones, with ripple-marks and some other markings	16½	216
6.	Coarse-grained, friable sandstone, below which the zone is mostly covered, with perhaps an occasional layer shown	16½	199½
5.	Coarse-grained, quartz, gray, brownish-spotted, friable, cross-bedded sandstone, which is rather thin-bedded.		

No.		Thickness. Feet.	Total thickness. Feet.
	The sand in this zone is rather fine, white quartz. This outcrop is in the road gutter, opposite the second house on the eastern side of the road, above the four corners, and is the lowest exposure of the coarse-grained, Berea sandstone seen in the road	8±	183
4.	*Bedford formation.* Composed of grayish shales and shaly sandstones shown in the highway gutters, all of which belongs in the Bedford formation, which therefore has a thickness of at least 40 feet, and it may be greater. The barometer, in 1909, gave the thickness of the interval from the base of the first black shale seen to the base of the coarse, Berea sandstone, as 75 feet. This is the same as the former measurement for the thickness of the Cleveland shale and Bedford formations taken together	40	175
3.	*Cleveland shale.* Very black, bituminous shale shown in the gutters and highway banks. The top of the black shale occurs a few rods north of the four corners, and it extends down the hill below the watering trough	35	135
2.	*Chagrin formation.* About 20 feet of grayish and very rusty-colored, shaly sandstones, which contain an occasional fossil, and are shown in the gutter and highway bank. The top of the Chagrin is barometrically 365 feet higher than the bed of the Grand River, in Painesville, below the Abbott Mill and river bridge	20	100
1.	Covered interval of alluvial or drift deposits to the level of Gordon Creek	80	80

It will be noticed that the thickness of the Berea sandstone in the above section is almost identical with that of the same formation in Stebbins Gulch, some four miles to the southwest, where it is 69+ feet thick.

Blackish shale occurs on the road higher than the Curtis quarry, and 45 feet higher barometrically than the quarry are thin-bedded, bluish sandstones which were noticed at about the highest point on the road before reaching the school-house and first four corners to the south of the quarry.

On the road running east from the four corners mentioned in the above section there is a small but fairly steep hill composed mostly of Berea sandstone which is exposed on top of the hill, and the lowest exposed beds of coarse-grained, massive sandstone are shown by the roadside on its eastern slope 40 feet below its summit. Part of this sandstone, at least, is rather friable so that its wash readily forms beds of loose sand at the foot of the steep slope. From the top of the hill this road may be followed northeasterly for 1.7 miles into the valley of Big Creek at the upper end of Cascade Hollow. There are occasional

outcrops of Paleozoic rocks along this road which may be represented in the following section:

Section from Cascade Hollow along the Highway to the Southwest.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Berea sandstone.* Coarse-grained, massive sandstone, part of which at least is very friable, extending to the top of the hill. Forty feet is more or less completely shown, according to the barometer, and at about the same level as the base of zone No. 6 in the section from Curtis quarry to Gordon Creek	40	235
3.	Mainly covered, but showing layers of thin-bedded, buff sandstones and shales in the highway gutter east of the four corners, and near the base of the interval, in which is the Bedford formation	35	195
2.	*Cleveland shale.* Very black, bituminous shale, which is well shown in the highway gutter just above the house of Charles Burr, opposite which is its base. The shale is partly covered, but fairly well shown for 22 feet, by the level, and the buff sandstones appear about 3 feet above the highest outcrop of shale. The barometer gave 25 feet for this same interval	25±	160
1.	*Chagrin formation.* Bluish-gray shales and thin sandstones are shown in the highway gutter just below the Charles Burr house. This interval is more or less covered until the banks of Big Creek are reached at the upper end of Cascade Hollow, at the iron bridge, near the house of M. J. Pease, where the shale is well shown in the bed and banks of the stream	135	135

The Cleveland shale is also shown in the gutter on the State Road below the first house northwest of the four corners where it is crossed by the Cascade Hollow road. In the road gutters below the four corners are frequent exposures of the Bedford formation, which consists of shales alternating with rather frequent layers of thin-bedded sandstones.

The Berea sandstone is shown in a gutter on the State Road southeast of the first house to the south of the four corners and then may be seen for some distance along the road as far as the vicinity of the farmhouse of Mr. Alfred Brown.

Following the contour lines on the topographic map this upper ledge of sandstone would continue around to the hill mentioned in the section just described and cross the Chardon-Concord road about 40 feet lower than the Curtis quarry.

Between the Curtis quarry and Chardon there are comparatively few outcrops of Paleozoic rocks on or near the highway. On Rider Creek, however, where it crosses the Hosford farm on the western side of the highway and about 2 miles northwest of Chardon, are ex-

posures of bluish to blackish thin and even-bedded shales with an occasional layer of thin sandstone varying in thickness from 1 to 5 inches.

The top of the exposure is between 55 and 60 feet, according to the barometer, lower than the base of the Sharon conglomerate in Rocky Cellar and the highest shale is bluish in color and rather arenaceous, but mostly with fine laminæ although there is an occasional sandy layer one-half inch or so in thickness. Some 20 feet below the top of the exposures a layer of fine-grained, gray sandstone about 5 inches thick crosses the bed of the creek and also shows on the bank farther down stream. Immediately above and below this sandstone the shales are principally argillaceous, soft and bluish to blackish in color. Beneath the 5-inch sandstone are more conspicuous arenaceous shales to thin layers of sandstone from 1 to 3 inches in thickness, which alternate with zones of shale from 1-foot up. These shales have the general lithologic appearance of the Brecksville except that in the lower part the sandstones are thicker and more conspicuous than in the typical section in the Cuyahoga Valley. These outcrops occur in the woods on the Hosford farm between the highway and railroad where 30 feet is shown.

Another small outcrop occurs on the eastern side of the road a few rods north of the John Makee house, rather more than a mile from the square in Chardon, and not far south of the first crossroad north of Chardon which runs easterly across Big Creek. It forms a small fall in a branch of the second stream crossing the road north of Chardon. About 7 feet of blue shaly sandstone and shale is shown and the sandy layers weather to a rusty color. The higher part of the bank is composed of drift. The older rocks in this outcrop apparently belong near the top of the Cuyahoga terrane of this region. The top of these shales is about 145 feet lower than the Chardon Park and by the barometer 22 feet lower than the base of the Sharon conglomerate in Rocky Cellar, a glen to the northeast of Chardon.

The average of two readings of the barometer made the difference in altitude between the top of the Curtis quarry and the base of the Sharon conglomerate in Rocky Cellar 84 feet. The distance between these two localities is 4.2 miles so that the dip has reduced the apparent thickness of this interval which represents the Cuyahoga terrane.

Sections on Big Creek.—Big Creek rises in the southwestern part of Hambden Township and flows across part of Chardon, LeRoy and Concord townships into the Grand River. In the upper part of its course the banks are composed mainly of alluvial and drift deposits; but from the northeastern part of Chardon Township to its mouth they are as a rule steeper and frequently reveal considerable banks of Paleozoic rocks. In the western part of LeRoy Township, about 5 miles southeast of the center of Painesville, is a part of its gorge

known as Cascade Hollow. This part of the gorge begins not far below the iron bridge at the three corners near the house of M. J. Pease. The rocks in the bed of the stream at this locality are about 135 feet below the top of the Chagrin and the gorge of Cascade Hollow has been cut out of the same formation. About two-fifths of a mile below, East Creek enters Big Creek from the east, forming a fall said to be 60 feet in height. This fall is below the Red Bridge, while above it in Big Creek is another fall reported as 18 feet high. Some of the banks along this portion of the creek are said to be 160 feet high and the Chagrin formation extends well toward their top. It consists at this locality of layers of rather thin shaly sandstone from 5 to 10 feet apart with the intervals composed mainly of bluish-gray shale in which are layers of sandstone from a fraction of to more than an inch in thickness, while the heavier sandstone zones are from 6 inches to perhaps a foot in thickness and form projecting ridges on the otherwise nearly smooth banks. This is a good locality in which to study the upper portion of the Chagrin formation and may be readily reached from Painesville. The banks of the stream from this locality on down to where it enters the Grand River, a mile or so from the boundary of Painesville, are generally steep and rocky. In Moody Hollow not far above its mouth are steep and high banks affording fine outcrops of the Chagrin formation. There is probably fully 350 feet of the upper portion of the Chagrin formation shown on this stream.

South of the State Road in the southeastern part of Concord Township the western bank of Big Creek is steep. The Paleozoic rocks are not deeply covered and so they occasionally come to the surface or are shown in the small runs. In the bed of Big Creek a little farther south than on an east line from the house of Warren W. Winchell is an exposure of fossiliferous Chagrin shale. The layers are rather coarse, blue in color and some of them contain numerous specimens of *Spirifer disjunctus* Sowb., *Camarotœchia orbicularis* Hall (?), and *Athyris polita* Hall (?). This is a fairly good locality in which the fauna of the Chagrin formation may be collected and for some distance its shales generally form the bed of the creek. The complete fauna obtained from these shales in the bed of Big Creek at this locality is as follows:

1. Spirifer disjunctus Sowb. .... (a)
2. Camarotœchia orbicularis Hall (?)............................ (a)
   These at least are like the specimens from this formation which have been referred to this species. There are, however, only about 16 to 18 plications, while the description calls for 24.
3. Athyris polita Hall (?) .... (c)
   Some of the specimens are rather broad, and in that proportion approach *A. angelica* Hall; but they probably belong to *A. polita* as was found when similar specimens were compared with types of that species.

4. Cyrtia alta Hall ---------- (c)
5. Reticularia præmatura (Hall) Schuchert---------- (rr)
6. Liorhynchus mesicostale Hall (?) ---------- (rr)
7. Productella sp.---------- (rr)
8. Parallelodon cf. chemungensis Hall ---------- (rr)
The specimens are not well enough preserved for positive identification; but this species is reported by Professor Hall from the Chemung at Meadville, Pa. (Pal. N. Y., Lamellibranchiata II, p. 351), where several other species of this fauna occur.
9. Loxonema sp. ---------- (rr)
Three volutions are shown and the suture is banded like that of *L. delphicola* Hall.

The Chagrin formation according to the barometer, extends at least 56 feet up the bank where the highest rusty thin sandstones from 2 to 3 inches thick outcrop; while similar ones are shown lower which when unweathered are bluish-gray in color. Then there is 9 feet more or less completely covered, above which broken, black bituminous shale is rather clearly shown on an angle of the bank. There seems to be no question but that this shale occurs in the bank at this horizon and represents the Cleveland.

Higher and a little north of the Winchell house is a large spring from which the Concord Crystal Spring Water is bottled for the market. It is reported to be a very pure drinking water and there is an excellent flow so that it has formed a small gully. On the hillside, perhaps 6 or 8 feet higher than where the water is taken, is a ledge of sandstone composed of rather small white quartz grains, which are considerably rusted on the exposed surface; but with the lithologic appearance of the Berea sandstone. It is probable that the water works down through this sandstone and formerly emerged near its contact with the Bedford shale and lower has cut the small gully in the face of the hillside.

About half way between the Winchell and E. P. Brown farm-houses is a longer run than most of those on this hillside, which shows the Paleozoic rocks for a considerable part of its steep course. It heads not far below the highway and a few rods south of the house located between the Winchell and Brown houses. From the exposures in this gully and a parallel and shorter one a short distance to the south, the following section has been prepared:

Section on Big Creek between the Winchell and Brown Houses.

No.		Thickness. Feet.	Total thickness. Feet.
7.	Thin sandstones to arenaceous shales, which are composed mainly of fine, white sand grains, alternating with bluish to grayish shales. This zone probably belongs in the upper part of the Bedford formation, although		

No.		Thickness. Feet.	Total thickness. Feet.
	some of the thin sandstones are composed of sand of light color similar to some of the finer grained sandstones of the Berea	16	114
6.	Mainly blue, argillaceous shale, but with an occasional layer of very thin sandstone	6	98
5.	At top, thin layer of sandstone, composed of fine, white quartz grains somewhat like those of the Berea. The remainder of the zone composed of blue shales and thin sandstones, which are rather argillaceous, and unlike those of the Berea in composition	27	92
4.	Layer of grayish sandstone, 2 inches in thickness	$\frac{1}{6}$	65+
3.	Below the sandstone is bluish-gray shale, then a little that is almost black in color, while the lower part of the zone is a coarse, arenaceous, dark-gray shale. It is evident that the 2-inch sandstone (zone No. 4) is in the Bedford formation, and perhaps the shale of the present zone; but it is to be remembered that in Stebbins Gulch there is a somewhat similar shale in the upper zone of the Cleveland, which is limited above by a thin sandstone	5	65
2.	Covered interval	34	60
1.	*Chagrin formation.* Composed mainly of bluish, argillaceous shale to the level of Big Creek. On the creek bank it is somewhat fossiliferous, specimens of *Spirifer disjunctus*, Sowb. being the most abundant. *Camarotœchia orbicularis* Hall (?), and *Athyris* cf. *polita* Hall were also collected. In the smaller gully, a few yards to the south of the longer one, commencing at creek level, 22 feet of Chagrin shale was seen, with a 3-inch sandstone layer at the top	26	26

In the above section perhaps No. 3 represents the top of the Cleveland shale; but the greater part of it, at least, occurs in the covered interval of No. 2. If the remainder of the section from No. 3 to the top belongs in the Bedford then 49 feet of that formation is shown in this gully.

In a small stream west of the E. P. Brown house and old factory, from which water was formerly taken for the factory, is a small outcrop on its bank of coarse-grained, soft Berea sandstone. This locality is in the woods some rods up the stream from the old factory and the outcrop is 20 feet higher than the top of the last described section. The rock is typical soft Berea sandstone and shows that the base of this formation is here more than 116 feet higher than the level of Big Creek while on the H. H. Stone farm, 1.6 miles to the west of south, it is in the creek bed.

In Big Creek on the Mary A. Haldeman farm, which is the next one south of the E. P. Brown farm and the most northern one in Chardon Township, are outcrops of argillaceous, soft blue shale which are within

a few feet of the top of the Chagrin formation. This is a little farther south than where a direct easterly line from the Haldeman house would cross the creek, where the outcrop occurs in the lower part of the eastern bank at low water and also partly forms the floor of the creek. The shale, which is called soapstone by the farmers, is rather fossiliferous and contains *Spirifer disjunctus* Sowb., *Dalmanella tioga* (Hall) Wms. and *Productella* sp.

About 120 feet farther up the creek, on the same side and about 3 feet higher than where the fossils were collected, is the contact oi the Chagrin and Cleveland shales. The contact may be seen by examining the bank closely, where just above the soft Chagrin shale 3½ feet of very black characteristic Cleveland is shown. The Cleveland comes out in large, thick blocks of massive shale, which on weathering split up into the thinner characteristic laminæ.

A few rods farther up the creek the contact is clearly shown on the northwest bank, where the massive Cleveland shale projects beyond the soft Chagrin shale. Again on the opposite bank slightly up stream is the Cleveland shale and then a small anticlinal fold occurs which brings up the Chagrin, but it drops down again to creek level at the fence. There is also indication of considerable dip to the east of south when the position of the shales on opposite sides of the stream is compared. Above the fence is a bank of high drift material and a little farther up stream than its base, Cleveland shale occurs on both sides and in the bed of the creek, with a bank nearly 5 feet high on the southeast side. Farther up the stream are more banks of boulder clay and sandy drift.

Between the exposures just described on the Haldeman farm and the higher ones on the E. P. Brown farm, about on the township line, is a bank perhaps 40 feet high composed mainly of sand, which is stratified to some extent, with apparently some clay near its base. A recent land slide had left the upper part nearly perpendicular, as seen in the fall of 1906, and the sand deposit was beautifully shown.

One mile above the outcrops of shale on the Haldeman farm and about one-half mile above where the Griswold Hollow road crosses Big Creek, are interesting beds of sandstone on the former farm of H. H. Stone; but in 1909 owned by Joe Baumgartner.

Section on Baumgartner Farm.

No.		Thickness. Feet.	Total thickness. Feet.
10.	*Berea grit.* Coarse-grained, rather soft, gray rock, composed of white quartz grains, which is shown in small run entering Big Creek from the east. The sandstone of this highest zone is partly covered; but apparently part of it is cross-bedded. At an earlier visit, outcrops of this zone were noted, extending some 4 feet highe1	12±	37

No.		Thickness. Feet.	Total thickness. Feet.
9.	Cross-bedded, massive zone, the top of which makes a small fall in the run	$4\frac{2}{3}$	25—
8.	Ripple-marked zone	$\frac{3}{4}$	$20\frac{1}{4}$
7.	Strongly cross-bedded zone of coarse-grained, quartz sandstone	$10\frac{1}{2}$	$19\frac{1}{2}$
6.	Massive, coarse-grained, friable sandstone, in which are hard lumps like concretions, which are conspicuous on a weathered surface. This zone is well shown in the lowest ledge of Berea sandstone, on the eastern bank of the creek, a short distance above the second fall	$1\frac{1}{3}$	9
5.	Thin-bedded, even-layered, coarse-grained, quartz sandstone, containing beautiful and frequent examples of ripple-marks. The layers vary in thickness from $\frac{1}{2}$ inch to $2\frac{1}{2}$ inches, or slightly more	$1\frac{3}{4}$	$7\frac{2}{3}$
4.	Shale zone composed of thin layers of rather bluish sandstone, which consists of coarse, rounded, white quartz sand, alternating with layers of rather soft, bluish shale. In this zone there is a considerable amount of the bluish shaly material, mixed with the sandstone. The sand is white quartz, larger than the grains in the subjacent sandstones, and is like that of the Berea, while the shaly material is perhaps more like that of the Bedford. It looks as though the blue Bedford shale had been worked over and mixed with the Berea sand. The coarser layers of sandstone have numerous examples of small ripple-marks, with the crests from 1 to 2 inches apart. The shale shows splendid examples of sun-cracks, extending almost to the very base of the zone, some of which have fillings an inch in width. The chemical composition of the lower part of this shale, according to Professor Demorest's analysis, is as follows: Clay, 13.1%; quartz, 65.5%; feldspathic material, 20.2%, Fe_2O_3, 1.2%. The above description is drawn up mainly from the exposure on the western bank of the creek, just above the second fall; but farther up the stream, on the opposite bank, this zone is thicker, varying from 1 foot 11 inches to 2 feet. This shale zone apparently rests directly on the subjacent blue, compact Bedford sandstone	$1\frac{3}{4}+$	$5\frac{11}{12}$
3.	*Bedford formation.* Stratum of gray to blue (bluish-gray when wet), compact sandstone, composed to a considerable extent of very fine grains of white quartz sand. These grains of sand are much finer than those in the zone above, and do not resemble the grains of Berea sand. This stratum varies in thickness from 9 to 10 inches, and makes the second fall in the creek. Professor Demorest's analysis of this sandstone is as follows: Clay, 9.9%; quartz, 74.6%; feldspathic material, 13.5%; Fe_2O_3, 2%	$\frac{3}{4}+$	$4\frac{1}{6}$
2.	Soft, blue, argillaceous shale, alternating with thin layers of sandstone, which are composed of grains of fine white		

No.		Thickness. Feet.	Total thickness. Feet.
	sand. This shale zone is like that of the Bedford formation, and the shales weather to the brownish or reddish color on the outside, so frequently seen in the Bedford sandstones. The zone varies in thickness from 1 foot 10 inches to 2 feet	$1\frac{5}{6}$	$3\frac{5}{12}$
1.	Compact, light gray to bluish, fine-grained sandstone, which makes a small fall in Big Creek nearly below the Baumgartner house, and forms the base of this section. It is composed of fine, white quartz grains of sand similar to those composing the lowest sandstone layer in Griswold Hollow (which will be described shortly), and the barometer gave the same level for the two layers. The surface of part of this stratum is weathered to a brownish or reddish color. At least 19 inches is shown in the fall, and the layer is probably thicker; but its base could not be seen	$1\frac{7}{12}$	$1\frac{7}{12}$

About 9 feet of the lower part of the Berea sandstone is also shown on the eastern bank of Big Creek, just above the second low fall. The third fall or rather cascade in Big Creek at this locality is over these lower thin and cross-bedded sandstones. On the eastern bank opposite the cascade and not far above where the run from the east enters Big Creek, is an excellent spring which emerges from the lower thin-bedded Berea sandstones. Good springs are of somewhat frequent occurrence in the lower part of the Berea sandstone as is to be expected when its texture is considered together with the fact that it is underlain by a formation composed mainly of a more or less impervious shale. Professor Carney has called attention to a similar water-bearing formation in central Ohio—the Black Hand—which is underlain by the Cuyahoga shales and fine-grained sandstones, and described its importance in determining the location of the farm-houses.[1]

There may be some question in the above section as to what horizon shall be considered the base of the Berea formation. The writer considers that the 9-inch sandstone stratum, No. 3 of the section, is the top of the Bedford formation as found in this creek. The fine-grained sandstone of zones 1 and 3 are lithologically like those of the Bedford formation, being much harder as well as finer grained than the Berea, while the intermediate shale zone is also lithologically like the shales of the Bedford. Again, just above the 9-inch sandstone begin thin, layers of sandstone composed of coarse, rounded grains of quartz sand, numerous layers of which show distinct ripple-marks and others suncracks.

It appears to the writer that the upper part of the Bedford formation

[1]Pop. Sci. Monthly, Vol. LXXII, 1908, pp. 503-11, and reprinted in Bull. Denison Univ., Vol. XIV, 1909, pp. 146-155.

was eroded down to one of its hard and thicker sandstones. It became perhaps a land surface and later on top of this Bedford sandstone was deposited the first of the Berea sands. This sand was also mixed with some clayey material, probably derived from the Bedford. Some of the time at least it was uncovered so that it dried and cracked making sun—or mud—cracks. Also in the sand deposits of the shallow water numerous ripple-marks were preserved.

After about 20 inches to 2 feet of this type of deposit came the continuous coarse deposits. The lower ones are even-bedded, coarse-grained sandstones, splitting into fairly thin layers which are succeeded by a rather massive layer, and then conspicuously cross-bedded ones. In other words, it appears to the writer that the coarse deposits of zone 4 constituting the base of the Berea formation rest *disconformably* upon the sandstone stratum of zone 3 which is considered the top of the Bedford formation as shown in this section. This explanation will receive additional support from the section in Griswold Hollow on Jenks Creek, one-half mile to the northeast, a description of which will be found a little farther on in this bulletin.

Recently certain geologists have expressed the opinion that the Berea sandstone is a continental rather than a marine deposit. The writer's attention was first called to this theory of its deposition by the statement of Dr. Grabau which opinion has later been more fully expressed by Professor Cushing who states that an uplift occurred at the close of Bedford deposition. This uplift increased the grade of the stream which bore down quantities of sand and spread it out in broad flats in the lower parts of their courses and as delta deposits at their mouths.

The cross-bedding, ripple-marks and sun-cracks noted in the description of certain layers in the preceding section, have generally been regarded as characteristic of shallow water deposits. Our latest American text-book of geology states that "These characteristics [with which were also included rill-marks, tracks of land animals and fossils of organisms that lived in waters of slight depth] are sufficient to differentiate sedimentary formations made in shallow water from those made in deep water, even after they have been converted into solid rock, and after the rock has emerged from the sea. Many of these characteristics are, however, shared by deposits made by streams on land."[1] It will be noted that although the above named authors cite those characteristics as in general evidence of shallow water deposits, still they also recognize them as occurring in deposits made by streams on land.

Professor Scott stated that sun—or mud—cracks "may be preserved indefinitely in rocks which are formed from flood-plain accumulations. In such deposits there is apt to be a difference in the material thrown down in the earlier and later stages of the flood, because of the

[1]Chamberlin and Salisbury: A College Text-book of Geology, 1909, pp. 320, 321.

difference in the velocity with which the waters move. After the river ceases to rise, the water over the flood plain becomes almost stagnant and lays down very fine material, which thus forms the cracked surface. When the next flood arrives, it carries coarser material, frequently sand, which fills up the cracks and thus preserves them. Mud cracks are formed under other conditions * * * but probably nowhere on such an extensive scale as on the flood plains of rivers which flow through arid regions."[1]

Geikie states that "sun-cracks could not have been produced so long as the sediment lay under water. Their existence therefore among any strata proves that the surface of rock on which they lie was exposed to the air and dried, before the next layer of water-borne sediment was deposited upon it."[2]

Professor Barrell in his studies for students has made the following statements concerning this subject:

"The flood-plain of an aggrading river covers a wide area, in the case of the larger rivers measured by thousands of square miles. It is all periodically subject to inundations which may last for a few days or weeks, but leave the greater part of the surface exposed to the air during much of the year. The invading flood waters frequently sweep sand with them, but after the flood is at its height the waters drain away quietly and much of the fine clay is deposited from suspension. Thus on river flood-plains there is peculiar liability to form well interstratified deposits of sand and clay; to fill up the last-formed mud-cracks with coarser material, and hence permanently to record them through the varying composition and structure of the formation. Such successive strata of the same nature may be indefinitely accumulated."[3] In his "conclusions on geological significance of mud-cracks" he summed up the evidence as follows:

"It would seem that next to coal beds formed *in situ*, or abundance of land fossils belonging to the animal kingdom, that mud-cracks form one of the surest indications of the continental origin of argillaceous deposits. The structure is also seen most commonly to originate under climatic conditions where the other tests are apt to fail.

"It may be considered, therefore, that mud-cracked shales predominantly indicate former flood-plain deposits, usually on delta surfaces which have displaced shallow seas."[4]

The base of the Berea sandstone in the creek at this locality is by the barometer about 188 feet below the base of the Sharon conglomerate in Rocky Cellar, about 2.4 miles to the east of south. If the Berea formation is 61 feet in thickness as in Griswold Hollow one-half mile to

[1]An Introduction to Geology, 2d ed., 1908, p. 206.
[2]Text-book of Geology, 4th ed., Vol. I, 1903, p. 643.
[3]Jour. Geology, Vol. XIV, 1906, p. 540.
[4]Ibid., p. 550.

the northeast, then its top in this glen is 127 feet below the base of the Sharon conglomerate. This agrees very closely with the thickness—125 feet—of this interval as obtained by barometer readings between the base of the conglomerate in Rocky Cellar and the top of the Berea grit in Griswold Hollow and also the base of the conglomerate north of North Chardon and the Berea grit at the same locality.

Farther back from Big Creek and higher than the outcrops of Berea sandstone are banks of boulder clay and other drift material. The two succeeding banks above the third fall are composed of drift material and near the creek on the second bank is blue boulder clay. The creek was not followed from this bank until near the Robinson bridge about one and one-half miles farther up stream. A drift and clay bank is shown below the bridge while between it and the run on which is Rocky Cellar there are numerous exposures of boulder clay. In this latter interval at different localities are four or five rather high banks of clay; the highest one from 20 to 25 feet, but its upper part is less pure clay and apparently more sandy than the compact bluish clay which forms the lower part. The boulders in the clay, as a rule, are not large, and perhaps better be called large pebbles. In the fields an occasional boulder of jasper pebble conglomerate was noticed.

Outcrops Near Painesville.—On the banks of Grand River above Painesville are excellent exposures of the Chagrin formation. On the Grand River and Big Creek in and near Moody Hollow from one mile to a mile and a half south of the New York, Chicago & St. Louis Railroad are high banks of the Chagrin which give fine exposures of the formation. At this locality Mr. M. C. Read in the Lake County report gave the thickness of the Erie shale [Chagrin formation] where the river cuts through South Ridge, as from 80 to 100 feet to the bed of the stream, superjacent to which is from 30 to 50 feet of blue clay, then 3 to 4 feet of mixed sand and blue clay and finally 60 feet of yellow clay with sand at the top.[1] The rocks consist of shales alternating with thin sandstones and the outcrops with interruptions continue up the creek to the lower sections already described under the heading of Sections on Big Creek.[2] The outcrops of the Chagrin formation may be studied to advantage in these fine ravines in the vicinity of Painesville. The slopes of the banks are more or less covered with evergreens and the high, rocky walls make attractive ravines which in the Moody Hollow region are picturesque.

One reading of the barometer was taken in Moody Hollow and another at the top of the Chagrin formation on the Chardon-Concord road rather more than a mile to the south of Concord and about 2.8 miles south of Moody Hollow which gave a difference in altitude of

[1]Geol. Surv, Ohio, Vol. I, 1873, p. 517.
[2]Page 567.

345 feet. It appears safe to say that at least the upper 350 feet of the Chagrin formation may be studied in outcrops near Painesville commencing in the Grand River at that town and continuing up its branches to the south.

Dr. Newberry in 1889 discussed the thickness of the Erie shale [Chagrin formation] in this region as follows:

"At Painesville the Erie shale, by the boring made at General Casement's house, was proved to have a thickness of seven hundred feet, and there to rest upon black shale, from which it was sharply separated. From two hundred to three hundred feet of the upper portion of the Erie shale are here wanting, having been removed by erosion; but this portion may be seen by following up the valley of Chagrin River. Hence we have evidence that there the Erie shale is not far from one thousand feet in thickness and is essentially alike throughout; that is, is composed of soft dove colored shale, with flags of sandstone."[1] Mr. H. P. Cumings, city engineer of Painesville, wrote concerning the location of this well that he did not know whether "it is on high land or in the valley, but presume it is on the high land. This would be nearly 100 feet above the river. The fall in the river from Moody Hollow to this point I have never determined, but think it is not less than 10 feet and is perhaps 15 feet."[2]

Later it was learned that the gas well was drilled on the grounds of General Casement which are east of the Grand River and about one mile east of the Court House Park in Painesville and at about the same level. According to the barometer the level of Grand River below the highway bridge and Abbotts Mill is from 80 to 85 feet lower than the street opposite the Parmly House and Court House Park.

Chardon Outcrops.—The town of Chardon is located on a hill which is underlain by the Sharon conglomerate. About one-half mile northeast of Chardon Park, two small tributaries of Big Creek have cut small gorges in the conglomerate, which are nearly parallel and about 35 rods apart. They may be readily reached by going to the northern end of Maple Avenue and then for a short distance across the field to the northeast. The northern glen affords the better geological section, which will be described first, and the top of the outcrop by the barometer is about 93 feet lower than the sidewalk in front of the Chardon House, which is about 1,300 feet above sea level.

Section of Rocky Cellar.

No.		Thickness. Feet.	Total thickness. Feet.
3.	Highest outcrop of *Sharon conglomerate* as shown in field at head of gully. To a considerable extent the rock is a coarse, white quartz pebble conglomerate, in which		

[1]Mon. U. S. Geol. Survey, Vol. XVI, p. 129.
[2]Letter of Feb. 27, 1909.

No.		Thickness. Feet.	Total thickness. Feet.
	are large numbers of pebbles, and the other portions are simply grit, or very coarse-grained sandstone. The rock is considerably stained from iron, sometimes making rusty layers, and other portions are speckled by spots of rust; while portions of the cliff show conspicuous cross-bedding. Two readings of the barometer gave 30 feet each for the thickness of this zone, while the level made it 31 feet. Rather more than the lower 20 feet of the zone is well shown in the glen	31	39
2.	Covered interval	6±	8
1.	*Cuyahoga terrane.* Bluish-gray, mostly soft, argillaceous shale, but some is slightly arenaceous, shown in the run, and on the bank 2 or 3 rods below the base of the ledge of Sharon conglomerate. This shale has the lithologic appearance of the Cuyahoga, and undoubtedly is very near the top of that terrane. Springs appear in this gully, and at other similar horizons on the eastern side of Chardon, showing the contact of the Sharon conglomerate with the clay shales of the underlying Cuyahoga terrane	2±	2

In the stream of the southern gully a few rods below the conglomerate, a foot or so of bluish-gray Cuyahoga shale is shown. There is then a covered interval and the numerous fallen blocks of conglomerate render it difficult to determine accurately the base of the Sharon conglomerate. From the lowest layer actually seen in place, however, to the top of the exposure of the conglomerate is 38 feet.

The Sharon conglomerate is shown on North Hambden Street and in the small gully on its northern side. It is exposed, however, to a greater extent on South Hambden Street, where outcrops may be found to within about 20 feet of the top of the hill and to the watering trough well down its slope. There is also a small glen to the north of this street in which the conglomerate, according to the barometer, is shown about 5 feet lower than on the street. From the base of the outcrop in this gully to the highest ledge on the street, which is composed of coarse sandstone and white pebble conglomerate, is by the barometer 95 feet, all of which belongs in the Sharon. Neither its top nor bottom is shown, although the lower outcrops are probably not far above its base, and it can be said that in Chardon the Sharon conglomerate is 100 feet or more in thickness.

At the Chardon House, Mr. John Carver states that their well drilled in 1906 is 119½ feet deep and that it reached solid rock at a depth of 15 feet. It passed through some soapstone, but was mainly in sandstone and the water rises about 80 feet in it. Mr. Orange Cook thinks this well passed through the conglomerate. Mr. Cook stated that in the basement of the store occupied by Cook and Parsons, on

the northwest corner from the Chardon House, the conglomerate was found to be very hard from iron, while only a short distance away in digging for a fire cistern it was so soft that it could almost be shoveled out. Mr. Cook also reported that some years ago a well was drilled below the corner of Water and South Water streets, the second corner west of the Chardon House, which went into the Cuyahoga shales. He is not sure whether or not the conglomerate was found in this well; but probably it was since the mouth of the well is not much more than 50 feet lower than the Chardon House. Later the well was drilled deeper and enough oil was obtained to spoil the water, which shows that it is not safe in this village if good water is obtained to drill to any considerable depth in the Cuyahoga terrane.

It was reported by Mr. M. L. Maynard that many years ago a well was dug in the park to a depth of 95 feet which reached rock at a depth of 10 or 15 feet and the remainder was all sandstone or conglomerate. The Park House well, Mr. Maynard reported as 100 feet deep before water was reached, while the well at his house passed through 13 feet of sand and gravel and then 62 feet of Sharon sandstone and conglomerate before reaching water.

In the southeastern part of Chardon, on East King Street, the Sharon conglomerate is quarried by Charles Grant. The rock is not very pebbly in this quarry but is largely a coarse-grained sandstone which is obtained in rather large blocks that are used for bridge abutments and similar heavy work.

Griswold Hollow. — In the northeastern part of Chardon Township rather more than 3 miles east of north of the park in Chardon is a glen on Jenk's Creek an eastern tributary of Big Creek. This is generally known as Griswold Hollow, although recently it has been labeled Hemlock Glen. There is a fall of 45 feet over the Berea sandstone in the glen and a short distance farther up the stream is an old quarry. The following section was measured from the foot of the glen to the top of the quarry and on up Jenk's Creek:

Section of Jenk's Creek and Griswold Hollow.

No.		Thickness. Feet.	Total thickness. Feet.
9.	*Orangeville formation*, and perhaps this sandstone zone may be referred to the *Chardon*, although the interval between its base and the top of the Berea sandstone is greater than in Stebbins Gulch, and it is also thicker. Bluish, fine-grained, thin-layered sandstones, alternating with arenaceous and argillaceous shales. This sandstone zone is the highest rock shown on this stream, and from its base to the highest outcrop, the barometer gave a difference of 20 feet. Farther down the creek,		

No.		Thickness. Feet.	Total thickness. Feet.
	on its southern bank, where the sandstone caps a 32-foot bank of shale, Mr. Morse measured $13\frac{1}{4}$ feet of sandstone and shale; but apparently the outcrop on this bank does not extend to the top of the zone	20	128
8.	Bank composed mainly of black to bluish-black, argillaceous shale. An occasional layer of arenaceous shale to thin sandstone, however, occurs to within 8 feet of the base of the bank; below which it is composed entirely of black, bituminous shale. As leveled by Mr. Morse, this shale bank is 32 feet high, and the barometer gave 30 feet for it	32	108
7.	Covered interval to top of sandstone in old quarry. Barometer at one time made the difference 15 feet, and the second time less than 10 feet. Perhaps 10 feet is a fair estimate for this interval, although it is possible that it is not so great, in which case, the thickness of the shale separating the Berea sandstone and this upper one will not differ greatly from the thickness of the similar shale in Stebbins Gulch	10±	76
6.	*Berea sandstone* in old quarry a short distance above the fall, and the highest layer of the formation seen. It is a massive stratum, and probably very near the top of the formation. The sandstone may be followed up the creek, above the bridge, but the barometer indicated that the top of this outcrop was no higher than the top of the old quarry. In the bed of the creek, above the fall, one line of joints is finely shown, which run N. 40° W. The basal part of the fall is a massive, bluish-gray, coarse-grained sandstone, succeeded by a thin-bedded zone; these two lower ones with a total thickness of about 6 feet, then massive sandstone again, while thin, flaggy layers occur above the brink of the fall. From the foot of the fall to the bed of the creek above is 27 feet by level, while from the foot of the fall to the top of the old quarry is 45 feet by the barometer and 46 feet by the level	46	66
5.	Upper part of this interval covered as the creek is followed from the fall, but the lower portion is shown on the bank of the creek a few rods below the spring, and probably all of it a little farther down the stream on the northeastern bank, about opposite the house of Mr. V. S. Davis. It is fairly massive, somewhat coarse-grained, and rather soft, while the lowest 9 inches or so is very thin-bedded to shaly sandstone, with abundant ripple-marks, and one sandstone layer 2 inches or more in thickness contains numerous blue shale pebbles from the shale below. The quartz sand composing these layers has a rather bluish-gray color. The average of three readings of the barometer gave 10 feet for the thickness of this zone	10±	20
4.	Shale zone consisting of bluish shale, alternating with thin		

No.		Thick-ness. Feet.	Total thick-ness. Feet.
	sandstones as shown on bank of creek, opposite house of Mr. V. S. Davis. The writer obtained 5 feet 2 inches for the thickness of this zone, and Mr. Morse made it 5 feet 3 inches. The upper 3 feet of this zone contains more blue shale than sandstone, and there are even, thin layers of argillaceous shale, but there are also thicker layers composed of coarse, quartz sand. The upper one and one-half feet, however, is almost entirely a blue, rather tough, arenaceous shale. The extreme upper part of this zone is best exposed on the southwestern bank of the creek a few rods below the spring, where ripple-marks and large and conspicuous sun-cracks are beautifully shown. Some of the sun-cracks reach a width of $1\frac{1}{2}$ inches, with a length of 3 to 4 feet, and are mainly filled with the white quartz sand similar to that composing the superjacent, coarse sandstones, so that the lines in all their ramifications are sharply marked in the blue shale. The casts of the sun-cracks are also shown. These sun-cracks are among the largest and most conspicuous the writer has ever seen. Some of these largest cracks extend through several of the thin layers and look like joints mainly filled by the coarse, white sand of the Berea, which forms massive layers composed of coarse, white quartz grains a little higher on the bank. The chemical composition of the material filling these cracks is as follows, according to the analysis of Professor Demorest: Clay, 9.3%; quartz, 73.2%; feldspathic material, 16.5%; Fe_2O_3, 1%. In the lower 2 feet of this zone, thin, even layers of light gray sandstone predominate over the shale. The sandstone layers, from 1 to 2 inches thick, are composed of typical, rounded, coarse grains of Berea quartz sand. Some of them are ripple-marked, and these markings are more abundant in the coarser layers in the lower part of this zone. The shaly zone in general, as exposed on the bank of the creek, has a blue color, and there are numerous layers of thin sandstones from one-fourth to one-half inch in thickness, which show abundant ripple-marks, with the crests from 1 to 2 inches apart. Other layers show excellent examples of sun-cracks and their casts. The base of this zone is considered the base of the Berea formation in this section, which is separated by a *disconformity* from the subjacent Bedford formation. This section was reëxamined in August, 1909, and at this time, the barometer gave the same elevation for the base of the Berea formation on Big Creek below the Baumgartner house, as at this locality	$5\frac{1}{6}$	10+
3.	*Bedford formation.* Soft, blue, argillaceous shale, with some fine-grained, arenaceous shale to thin sandstone. One layer was noticed that showed ripple-marks;		

No.		Thickness. Feet.	Total thickness. Feet.
	but such markings have been noticed occasionally in the Bedford formation at various other localities. This zone varies from 6 to 8 inches in thickness and is a remnant of the upper Bedford shale, which it resembles lithologically, left above the subjacent sandstones----	$\frac{1}{2}$+	5
2.	"Blue stone" zone, the upper layer of which was shown in the bed and on the bank of the creek, after a freshet in July, 1907. It is a rather fine-grained, compact, bluish-gray sandstone, composed to a considerable extent of fine, white quartz grains. On the upper surface of this layer are markings which are probably worm trails, although it is possible that they are algæ. This rock was formerly quarried and called "blue stone" by the quarrymen; but when weathered and dry, it is really light-gray in color. The top layer is reported by Mr. V. S. Davis as 22 inches in thickness, below which is a lithologically similar layer 9 inches thick; but he does not know whether they are separated by shales or not. In August, 1909, 1 foot 9 inches of the upper layer was shown in the bank of the creek----------------------	2$\frac{1}{2}$+	4$\frac{1}{2}$
1.	A few rods farther down the stream than the "blue stone" zone, in July, 1907, was shown about 2 feet of soft, argillaceous shale, with some arenaceous shale, and two thin sandstone layers, varying from an inch to 2 or more in thickness. These are the lowest rocks which have been seen in place on this creek, the bed rocks for the remainder of its course to Big Creek being concealed by recent deposits ---------------------------------	2±	2

There may be a question as to where the line of division between the Berea and Bedford formations occurs in this section; but it appears to the writer that it is at the base of the shale zone, No. 4, which he thinks rests disconformably upon the subjacent shale. The "blue stone" occurs at the same level barometrically as the lower sandstones on Big Creek, one-half mile to the southwest, where the coarse-grained sand deposits rest directly on the second fine-grained sandstone. Also the readings in August, 1909, taken at the base of the Berea formation in each glen were identical. In the former locality it appears to the writer that all the upper shale of the Bedford formation was swept away while in Griswold Hollow from 6 to 8 inches of it is left on top of the upper sandstone. These two sections, only one-half mile apart, seem to show that the upper surface of the Bedford formation is uneven because of erosion and that the Berea sandstone rests disconformably upon the latter. This opinion is supported by the evidence of other sections in northeastern Ohio and in other regions of the state. If this interpretation of the structure be correct then at least 61 feet of the Berea formation is shown in Griswold Hollow. In August, 1909, the barometer

gave a difference of 60 feet from the base of the Berea formation to the top of the coarse sandstone ledge in the old quarry above the fall with an interval of one hour between the readings. The highest wall of the quarry perhaps is not the top of the formation, since a covered interval occurs in the creek before reaching the blackish shale, so that perhaps something is to be added to the 61 feet in order to obtain the complete thickness of the formation. On the Chardon-Concord road, about $1\frac{1}{2}$ miles to the northwest, there is 68 feet of the Berea formation.

On the northeast bank of the creek about opposite the house of Mr. Davis the shaly zone, or No. 4 of the above section, is well shown and after a small partly covered interval there is $16\frac{1}{2}$ feet of the massive, friable and coarse-grained Berea grit, about the lower two-thirds of which belongs in zone No. 5. A drift bank composed of clay, sand and gravel some feet in height occurs above the top of the sandstone. A little farther up the stream and on the opposite side is a spring. It is worthy of note that many excellent springs occur in the lower portion of the Berea sandstone and come to the surface either in this sandstone or near its contact with the subjacent Bedford shale.

On the western bank of Jenk's Creek above and below the highway bridge, the following section of the upper portion of the Berea formation was obtained.

Section of Upper Part of Berea Formation on Jenk's Creek.

No.		Thickness. Feet.	Total thickness. Feet.
4.	Top of exposed sandstone. Zone composed of coarse-grained; massive sandstone as shown on the bank overlying the subjacent shale	$10\frac{1}{4}$	17+
3.	Shale zone, composed in part of blue, argillaceous shale. Shown on bank above the bridge	2	$6\frac{5}{6}$
2.	Massive, coarse-grained sandstone, with ripple-marks. Shown on bank both above and below the bridge, but difficult to determine its exact thickness	4±	$4\frac{5}{6}$
1.	Shaly zone 10 inches thick in lower part of bank, just below the bridge culvert. Composed of rather coarse, but soft, even-bedded, argillaceous shale. The barometer gave this zone as 20 feet lower than the top of the sandstone in the old quarry	$\frac{5}{6}$	$\frac{5}{6}$

This locality is evidently the one referred to by Read in the county report where he stated that "at the northeast corner of the township, the Berea grit is finely exposed, and in both of these places [the other is given as the "Big Gull" which is probably Stebbins Gulch] there is a large part of it which will make grindstones equal to the best made at Berea."[1]

[1]Ibid., p. 524.

In the highway gutter below the house of Mr. Gaylord Robinson, south of Griswold Hollow, are bluish arenaceous shales alternating with argillaceous ones, the latter of which are blue in color. Some of the arenaceous shale tends to form very thin, even-bedded sandstone. Most of the interval beneath this zone along the road down to the Berea grit is covered; but in the road gutter near the foot of the hill east of the creek black argillaceous shale is shown. From the zone near the Robinson house down to the highest outcrop of the Berea grit is 82 feet according to the barometer.

The difference in elevation as determined by the barometer between the base of the Sharon conglomerate in Rocky Cellar and the highest exposures of the Berea grit in Griswold Hollow is 125 feet. The distance on a nearly north and south line between these two localities is 2.8 miles and as there is a southerly dip it is evident that the 125 feet does not represent the entire thickness of the Cuyahoga terrane for this region. The barometer also gave the difference in elevation between the base of the Sharon conglomerate on the highway not far to the north of North Chardon and the highest exposures of the Berea grit in Griswold Hollow, which is 2½ miles to the northeast, as 125 feet.

Hambden Township. — The central part of this township is comparatively high ground reaching an altitude of more than 1,320 feet above sea level, while on account of stream erosion there is lower ground toward the borders, especially the southern, western and northern. The streams as a rule have not cut very deep or narrow valleys and consequently there are not very many exposures affording sections of of any considerable thickness. On the G. M. Hanna farm, 2 miles northeast of Chardon Court House on the road to Hambden, a small run has cut a gully in the Sharon conglomerate, the head of which is nearly east of Mr. Hanna's house on the northern side of the highway. Most of the rock is rather pebbly and massive, with conspicuous joints which have been enlarged by erosion and in that manner the gully has been formed. There are lateral gullies entering the main one which have been formed by erosion along the cross-joints, that are called caves. At the upper end of the gully is a small cascade when there is a heavy run-off. The middle and lower parts of the cliffs in their highest portion are not so pebbly as in the lower; but there is considerable cross-bedding in the middle and upper parts. The coarse pebbles in the lower two-thirds of the cliff are finely shown in the gulch below the farm bridge, where many of them are of good size and some are decidedly large. The majority are composed of white quartz; but there are some of rose quartz and other colors. They are of various shapes and of varying degrees of smoothness. There are also occasional pebbles of dark colored limestone, chert, quartzite and other rocks as well as an occasional jasper pebble. The barometer indicated a thickness of about 40 feet for the exposed conglomerate in this gulch, which is a

rather attractive small glen. In its lower part some large blocks of the conglomerate have broken off from the face of the walls and fallen into it. In 1906 at the lower end of one of the ledges the rock was being dug out to some extent and hauled to Chardon for use as road material on the South Hambden Street hill. It was the partly decomposed portion of the ledge that was used for this purpose, or at least the sand matrix is not very firm so that the rock is readily pounded into gravel. Mr. Hanna thinks, however, that the conglomerate hardens on exposure and if one goes back under the soil that the rock is softer than on the exposed ledges.

About 1.8 miles northeast of Hambden is a gully known as the "Cooks rocks" on the Fenton farm, which was called to the writer's attention by Mr. M. L. Maynard of Chardon. The gully has been cut in the Sharon conglomerate and the top of the upper ledges is about 65 feet lower according to the barometer than the highest point on the highway just northeast of Hambden. Between 15 and 20 feet of the conglomerate is shown, which in general is composed of rather large pebbles, some of them larger than a hen's egg. White quartz constitutes the majority of the pebbles; but there are also some of rose and smoky quartz and one of feldspar was noticed. There are, however, poorly defined layers in the rock in which the pebbles are not abundant; but in general it is very pebbly, as above stated. Springs occur in the lower part of the gully at the base of the ledge, below which is a swale and perhaps the base of the ledge is near the base of the conglomerate in which case there is at least from 80 to 85 feet of the Sharon conglomerate in the central part of Hambden Township.

There is a rather conspicuous ledge of the Sharon conglomerate on the James Wedge farm, 2½ miles northeast of Hambden, in which is a small quarry that was known years ago as the Ireland. Most of the rock is a coarse-grained sandstone, rather brownish in color; but there are some quartz pebbles which are more abundant in the upper part of the ledge than in the main part of the quarry and ledge. The bedding is fairly even so that it splits into blocks which in 1906 were being quarried for bridge culverts. The base of the ledge according to the barometer is on the same level as the top of the outcrop at "Cooks rocks" and from the base to the top of the ledge above the quarry is 22 feet by hand-level. About 1½ miles east of the Ireland quarry on the eastern side of Bates Creek and in the northeastern corner of Hambden Township is Stony Hill which is capped by the Sharon conglomerate.

In the eastern part of Hambden Township in the valley of Bates Creek two oil wells have been drilled. They are 5½ miles northeast of Chardon and about two miles east of Hambden. The mouth of one well is on the Joseph Kiser farm on the southern side of the highway near the creek and some 130 feet lower than Hambden. The Kiser

well was drilled by the Knox Stock Company and finished in June, 1899. The following record of it was furnished by Mr. C. G. Kiser.

0′		Mouth of well
	35′	Quicksand
35′		
		Hard rock
	135′	Blackish shale
170′		Oil in Berea grit
	20′	
190′		Bottom of Berea grit
	310′ ?	
500′ ?		Gray sandstone, perhaps 20 feet thick
	1570′	Shale
2070′		Brownish shale containing oil
		Hard limestone
	398′	
2468′		Top of white sandstone
	32′	
2500′		Bottom of well

The oil-bearing portion of the sandstone was reported as rather porous and composed of fine white sand below which it changed to a darker colored one. Some gas and oil were obtained from the sandstone, the oil being confined to the upper 13 feet and below was salt water. Between 50 and 100 barrels of oil mixed with salt water was pumped out of the well.

In the above record the hard limestone struck at a depth of 2,070 feet probably represents the top of the Devonian limestone. The interval of 1,880 feet from the base of the Berea grit to the top of the Devonian limestone represents the Bedford formation and the Devonian shales. In Stebbins Gulch, nearly 9 miles to the west, the Bedford formation is 48 feet thick, and deducting this there remains 1,832 feet for the thickness of the underlying Devonian shales. In the Kenmore well between Akron and Barberton the thickness of the same interval is 1,690 feet, giving a greater thickness of 142 feet in the Kiser well. The thickness of 398 feet for the interval from the top of the Devonian limestone to the top of the subjacent sandstone in the Kiser well agrees closely with that of the same interval in the Hermitage well near Little Mountain, where it is 400 feet, or with that of 390 feet in well No. 4 of the United Salt Company on Madison Avenue, Cleveland.

In 1903 another well was drilled on the northern side of the road on the farm of Mrs. J. A. Huntoon in this same valley. The mouth of this well is about 10 feet lower than that of the Kiser well. It is reported that it yielded about 30 barrels of oil the first day and could be pumped for 12 hours at a time. Later the casing was split which

let in water and drowned the well. The samples from the bottom of the Huntoon well consist of grains of black and white sand.

A third well in this same general region was finished in June, 1904. It is located on the L. D. Eaton farm about one-half mile northeast of Hambden, near the Thompson road, and about 55 feet higher than the Kiser well. It is reported that the Devonian limestone was reached at a depth of more than 2,200 feet and that it was very hard in drilling. The well was drilled to a depth of 2,570 feet and the grains of sand from near its bottom are white in color and very fine, apparently quartz and indicate a hard sandstone with rather close texture. Some gas, but no oil, was obtained from this well.

Bates Creek Sections.—In the southeastern part of LeRoy Township on Bates Creek, which is also called Warners Creek, is a rocky gorge where the stream has cut through the Berea grit. Along the highway to the west of the gorge and Warner's mill are occasional exposures of rocks, especially near Kniffins Corners on the farm of G. W. Kniffins. Bluish-gray, fine-grained and thin even-bedded sandstone is shown just east of the corners which weathers to a buff color. This outcrop is in the Cuyahoga terrane, and by the barometer 70 feet lower than the base of the ledge of Sharon conglomerate at the Ireland quarry, one and one-half miles to the south in Hambden Township. In the gutter, five feet lower by hand-level, is soft grayish shale like the Brecksville with an occasional layer of thin sandstone. Still lower along the road gutter is blackish, very argillaceous shale, lithologically similar to the Brecksville. A mile and one-half farther northwest and above the road forks is a ledge of coarse-grained, iron-spotted sandstone which is apparently the northern outcrop of the Berea. At a higher elevation in the gutters along the road are first shales and then still higher shales and sandstones.

Below the outcrop above noted near Kniffins Corners, the rocks along the roadside are mostly covered until the top of the Berea grit is reached in Bates Creek above Warner's mill. This locality is nearly one-half mile to the east, and the top of the Berea grit by the barometer is 75 feet lower than the soft shales noted by the roadside. This indicates a thickness of 150 feet for the Cuyahoga terrane in the southeastern part of LeRoy Township. The rocks are fairly well shown along Bates Creek and the following section from the top of the Berea grit downward was studied.

Section on Bates Creek.

No.		Thickness. Feet.	Total thickness. Feet.
12.	*Berea grit.* Apparently the highest outcrops of the formation that are shown on the creek occur on its eastern bank above the mill, fall and highway bridge, just below the old dam. The highest layers are thicker		

No.		Thickness. Feet.	Total thickness. Feet.
	bedded than those immediately below, composed of coarse-grained sand, with an occasional ripple-mark. The layers also contain numerous markings like fucoid stems, but it seems rather improbable, since they are in this sand, that they represent such organisms	$4\frac{1}{2}$	$120\frac{1}{2}$
11.	Shaly zone with a 3-inch shale layer at the top; but composed mainly of thin-bedded sandstones, with a shaly layer of argillaceous to arenaceous shale 4 inches thick at the bottom	$3\frac{2}{3}$	116
10.	Thicker bedded sandstone, with some moderately thin layers, and numerous ripple-marks. The sandstone much iron-spotted	$4\frac{5}{6}$	$112\frac{1}{3}$
9.	Thin-bedded sandstone at brink of fall below bridge, on east and west highway	2	$107\frac{1}{2}$
8.	In the upper part of the fall, friable, very coarse-grained and cross-bedded sandstone; some of the layers of which are fairly thin-bedded. Lower, however, it is thick-bedded, and the best cliffs of this portion of the sandstone are on the eastern side of the creek below the mill, and above the lower highway bridge, where a heavy ledge of rather fine-grained, bluish-gray quartz sandstone occurs, some of which weathers to a brownish or slightly reddish tint. The barometric measurement for this zone is not satisfactory. One measurement from the fall, down the creek, gave but 31 feet, after deducting the lower zones of the formation, which were carefully measured. Another one, to the top of the cliff, above the lower bridge, on the eastern bank, gave 41 feet. It is thought that the upper layers of this cliff are below the zones described above, and as this measurement agreed better with a former one, it has been used for the thickness of this zone. There is an excellent spring in this zone on the eastern bank opposite the lower bridge. These lower zones are shown on the bank of Bates Creek, just above where a run or eastern branch enters it a few rods northwest of the highway, and in the lower part of the run	41	$105\frac{1}{2}$
7.	On bank of Bates Creek a ripple-marked sandstone, and also white quartz sandstone. Highest exposed layer at this locality	$\frac{1}{3}$	$64\frac{1}{2}$
6.	Blue shale, part of which is argillaceous. Sun-cracks in its basal part	$\frac{2}{3}$	$64\frac{1}{6}$
5.	Thin-bedded, coarse-grained, light-gray sandstone like best of Berea	$1\frac{1}{6}$	$63\frac{1}{2}$
4.	Shaly sandstone to shale, which is blue and some of it argillaceous, with thin layers of sandstone at the base which are composed of coarse, white quartz sand, with the lithologic appearance of typical Berea sand. The shales of this zone form the bed of the small run at its mouth, and also occur on the bank of Bates Creek		

No.		Thickness. Feet.	Total thickness. Feet.

above the mouth of the run, in which are splendid examples of sun-cracks that have been filled with quartz sand. Fig. 1 shows the appearance of some of these sun-cracks, with their ramifications as shown on the gradually sloping bank of Bates Creek a few yards above the mouth of the run. There are large and long ones which look more like the filling of joints. Some of the largest ones are 2½ inches wide, more than 2 feet in length, and of rectangular shape. These are all filled with white quartz sand, and the writer is uncertain whether they are joints that have been filled or

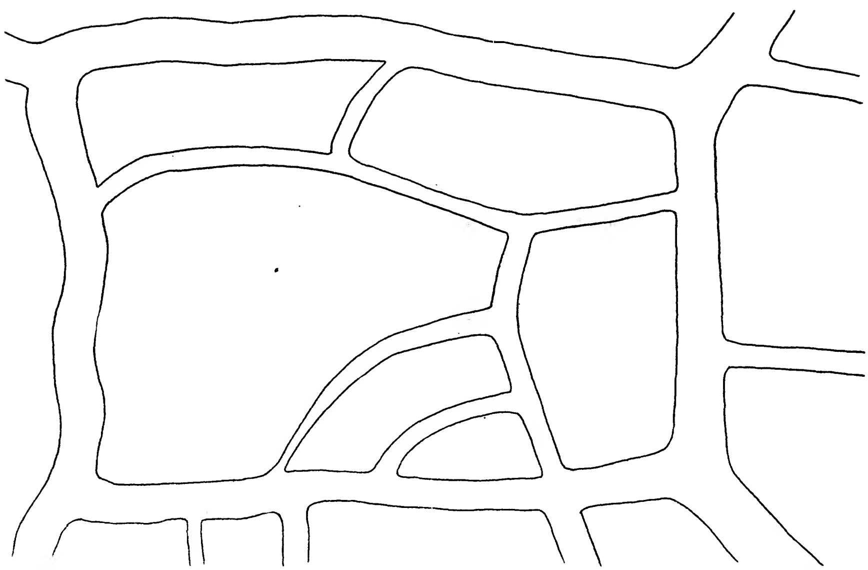


Fig. 23 —Sketch of mud cracks in lower shaly zone on Bates Creek southeast of Painesville.

sun-cracks. They are best shown on the eastern bank of the creek, just above the mouth of the run or eastern branch of Bates Creek. Numerous ripple-marks also occur in the thin sandstones of this zone, which are finely shown on the bank of the small run, and on the bank of Bates Creek just above the mouth of the run. When the water is low, blue, argillaceous shale of the Bedford formation may be seen under this zone in Bates Creek, in the little fall at the mouth of the run. This zone is very similar to the one described at the base of the Berea formation in Griswold Hollow.

In this section, which was made in August, 1909, the total thickness for the Berea formation, from its base to

No.		Thickness. Feet.	Total thickness. Feet.
	the top of the outcrops at the old dam, is 59¾ feet. Previously, the writer has stated that there was some difference in the several readings of the barometer for the Berea of this section; but it apparently gave a thickness of 55 feet for the continuous massive sandstone. It is possible that this highest exposed sandstone is overlain by a shale zone, and a higher sandstone one as shown on the branch of the creek, less than one-half mile to the east, in which case the thickness of these two zones is to be added to that of the underlying sandstones, in order to obtain the complete thickness of the Berea formation on Bates Creek ______________________	1 7/12	62⅓
3.	*Bedford formation.* A few rods farther down the stream, on the eastern bank, is a ledge, the upper part of which is a compact, fine-grained sandstone, varying in thickness at this point from 18 to 21 inches, which contains some clay pebbles. The actual contact with the Berea sandstone is not shown, however, at this particular locality. On the bank, just below the thick stratum described above, is a foot or more of blue, argillaceous and arenaceous shales, below which are blue, fine-grained, sandstone layers, from 1 to 3 inches thick, composed partly of fine, quartz grains, alternating with blue shale. This sandstone zone is about 15 inches thick, below which, to the creek bed, is 3½ feet of bluish, arenaceous shales, with thin sandstones; but the sandstones are thinner and fewer in proportion than in the superjacent zone. A little lower in the bed of the creek, is a blue, very compact sandstone, 2¼ inches thick, composed in part of fine, quartz grains. These quartz-bearing sandstones, however, are much finer grained and more compact than the Berea sandstones. In the bed of the creek, 9½ feet lower than the base of the 18+-inch stratum, is a compact, hard blue sandstone 3½ inches thick, containing fine, quartz grains. On the western bank of the creek, at this point, a section reaching up into the Berea sandstone has been measured in detail which follows the present one. Farther down the creek, and 25 feet lower, barometrically, than the 15-inch stratum (the section of this bank, however, apparently shows that the fall is 31 feet), is a high bank on the western side, reaching down to the water level, where the upper Bedford and lower Berea are clearly shown. The 15-18-inch sandstone stratum noted above, and a 10-inch one 2½+ feet higher, as noted in section on western bank of creek, are clearly shown in this latter cliff, and below the lower sandstone is 31 feet of shales, alternating with frequent layers of sandstone from 1 to 3 inches thick. Later, a detailed section of this bank will be given, on which 44¾ feet of Bedford is shown below the Berea. The barometer indicated that the top of the Cleveland shale, which		

No.		Thickness. Feet.	Total thickness. Feet.
	occurs on the opposite bank, only a few rods below, is 5 feet lower than the base of this cliff, although the writer is inclined to think it is not so much. This measurement, however, of 49¾ feet, has been taken for the thickness of the Bedford formation in this section..	49¾	60¾
2.	*Cleveland shale.* Tough, black, bituminous shale of typical lithologic character. Contact with the Bedford shown on the eastern bank at the edge of the stream a few rods below the high bank. At one place where the Bedford contact is shown, but not the Chagrin, about 11 feet of the shale is exposed, and near the middle is a thin, blue, sandstone layer, varying from one-half to an inch in thickness. In this part of the formation there is a tendency to slightly bluish, argillaceous and arenaceous shales, alternating with black ones, showing the coming in of lithologic characters, that farther eastward completely replace the black shale. The barometer at one reading gave this interval as 10 feet and at another one as 20 feet, the latter apparently the more accurate	11+	11
1.	*Chagrin formation.* Top of the formation shown in bed of the creek, where bluish shales and thin layers of sandstone occur.		

A little gully on the steep western bank of Bates Creek, not far below the eastern one where the upper deposits of the Bedford occur which have already been described, gives a complete section of the upper Bedford and lower Berea. This is an important section since it shows the contact of the two formations, hence it is given in detail.

Section on Western Bank of Bates Creek.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
9.	*Berea sandstone.* In general, rather massive, buff, fairly coarse-grained rock; but in part, especially in the upper portion, the layers are thin and cross-bedded. Ripple-marks also occur in the thin layers	28	--	46	3
8.	Thin layers of gray sandstone, composed of coarse grains of white quartz sand, alternating with blue shale, some of which is soft and argillaceous. There are sun-cracks which have been filled with quartz sand. Lowest layer composed of coarse, quartz sand like that of the Berea	1	7	18	3
7.	*Bedford formation.* Blue, argillaceous and arenaceous shale, with layers of thin sandstone, which are blue, fine-grained and compact	1	6	16	8

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
6.	Compact, blue, hard, fine-grained sandstone stratum	--	10	15	2
5.	Blue, argillaceous and arenaceous shale, alternating with thin layers of compact, blue sandstone, varying in thickness from a fraction of an inch to $1\frac{1}{2}$ inches, and composed of fine, white quartz sand	2	7	14	4
4.	Conspicuous stratum of compact, blue, hard and fine-grained sandstone. This stratum varies in thickness at several outcrops up to 21 inches, and the barometer read the same as at the thick stratum at the top of the bank, farther up stream, and on the opposite side	1	3	11	9
3.	Blue, arenaceous to argillaceous shale, alternating with blue, compact layers of hard sandstone, from a fraction of an inch to 6 inches in thickness	9	2	10	6
2.	Blue, compact, sandstone layer, composed of fine grains of sand, shown in bed of creek	--	4	1	4
1.	Blue, rather arenaceous shale in creek, below the sandstone stratum	1	--	1	--

In the above section it appears to the writer that the contact be-between the Berea sandstone and Bedford formation occurs at the base of zone No. 8, which is the base of the coarse-grained deposits. This zone also shows sun-cracks and resembles considerably the lower part of the Berea formation as already described in Griswold Hollow and on Big Creek, some five miles to the southwest.

This section on the bank and in a small gully was beautifully shown when visited in September, 1906, and August, 1907; but when visited in August, 1909, the contact of the two formations was covered by debris. On the steep bank, however, some yards below this gully the contact of the two formations was shown. At this point it is difficult to measure accurately very much of the bank, but the following zones near the contact of the two formations were measured by Mr. Morse:

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Berea sandstone.* Zone of thin, even-bedded sandstone composed of grains of white quartz	--	--
3.	Shaly to thin-bedded sandstone, the sandstones composed of coarse grains of white quartz. The lower 2 or 3 inches appears to be to a considerable extent reworked Bedford shale, mixed with coarse Berea sand, and also containing some small quartz pebbles	$1\frac{5}{6}$	$4\frac{2}{3}$
2.	*Bedford formation.* Zone of shale, and thin, blue, compact sandstone	2	$2\frac{5}{6}$

No.		Thickness. Feet.	Total thickness. Feet.
1.	Compact, blue, hard, fine-grained sandstone stratum, the continuation of No. 6 in the section a little farther up the stream, and the upper one of the two conspicuous sandstone strata near the top of the Bedford formation in this region	$\frac{5}{6}$	$\frac{5}{6}$

On the eastern side of the creek not many rods above the steep bank of Bedford and Berea, which has been briefly described above and following this paragraph will be described in detail, is a sharp small fold showing two anticlines and a small syncline. In the lower part of the bank the rocks have been broken about half way between the southern anticline and syncline, and the upstream part pushed over the lower for about a foot making a reversed fault with a displacement of about a foot. In the photograph of this bank, Plate LVI, A, the man's right hand is resting on the lower sandstone which crosses the fault, arches up the bank as indicated by the hammer and is thrust over the same layer and the superjacent shale.

The high cliff of Bedford and Berea formations on the western bank of the creek, about one-eighth of a mile below the upper bank and sections, is steep and difficult to measure; but it was leveled by Mr. Morse from the creek up to the base of the Berea sandstone. The steep bank of Bedford shale is continually wet from the water that works down from the Berea sandstone so that it is slippery and difficult to climb. This bank and the numerous springs along the Berea outcrops show that the formation is an excellent water horizon.

Section of High Cliff on Western Bank of Bates Creek.

No.		Thickness. Feet.	Total thickness. Feet.
8.	*Berea sandstone.* Massive sandstone capping the cliff, which is estimated as about 10 feet thick	10±	$60\frac{1}{2}$
7.	Shaly sandstone to shale at base of Berea. Some of the sandstone layers lenticular in shape	$\frac{3}{4}$	$50\frac{1}{2}$
6.	*Bedford formation.* Shale zone, but also containing some rather thin-bedded, compact, fine-grained, blue sandstones	$9\frac{1}{4}$	$49\frac{3}{4}$
5.	Stratum of blue, compact, fine-grained sandstone. The continuation of the upper Bedford sandstone noted in the sections on the bank farther up the creek	$\frac{5}{6}$	$40\frac{1}{2}+$
4.	Shale interval which was not measured on this bank and the thickness of $2\frac{1}{2}$ feet is taken from the one farther up the creek	$2\frac{1}{2}$	$39\frac{3}{4}$
3.	Stratum of blue, compact sandstone, which is the continuation of the lower one noted in the sections on the bank farther up the stream	$1\frac{1}{4}$	$37\frac{1}{4}$

No.		Thickness. Feet.	Total thickness. Feet.
2.	Bank composed mainly of shales with frequent thin layers of sandstone from 1 to 3 inches in thickness, which extends to creek level	31 –	36
1.	Mainly covered interval to top of Cleveland shale on opposite side of creek, a short distance farther down stream. Barometer gives 5 feet for this interval; but it may be less	5 –	5

These sections on the western bank of Bates Creek are very important in reference to the question of disconformity between the Bedford and Berea formations. The two sandstones described in the upper part of the Bedford formation on the western bank, the lower one 15 inches thick and the upper one 10 inches thick, hold the same relative position, and the upper one is noted in all these sections. The interval from the top of this 10-inch sandstone to the base of the Berea formation was carefully measured in the three sections. In the upper section this interval is 1 foot 6 inches, in the second one a few rods farther down the creek, it is 2 feet, while on the high bank about one-eighth of a mile farther down stream the thickness of the interval has increased to 9 feet 3 inches. This increase of 7 feet 9 inches in about one-eighth of a mile shows conclusively the uneven surface upon which the Berea sandstone was deposited in this region. It is to be noted that in all the sections showing the contact of the Bedford and Berea formations on Bates Creek, in Griswold Hollow, on Big Creek and in Stebbins Gulch there are two conspicuous sandstone strata of varying thickness near the top of the Bedford formation. It appears probable that they are the same two sandstone strata in all these sections, above the upper one of which was formerly a shale and thin sandstone zone of some thickness forming originally the upper part of the Bedford formation, a varying amount of which has been removed by erosion leaving an uneven surface upon which the coarse sands of the Berea formation were laid down.

A small tributary enters Bates Creek from the south (eastern side of creek in general) a short distance below the steep, high cliff where the Bedford and Berea are both shown. From the Cleveland shale up this gully the following section is shown, and the upper part of this run crosses the highway just northeast of the M. H. Thompson farm-house.

Section of Gully on Eastern Side of Bates Creek.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Berea formation.* Coarse-grained, quartz sandstone, the lower part of which is in very thin layers, but composed of coarse, quartz sand with some pyrites	4½	54¼
4.	Covered interval, which is partly shown farther up stream,		

No.		Thickness. Feet.	Total thickness. Feet.
	where shales and a sandstone stratum 8 inches or more in thickness were noted. Part at least of this zone belongs in the Bedford formation	8	$49\frac{3}{4}$
3.	Sandstone stratum, 21 inches thick, blue in color; composed of very fine, white quartz sand. This stratum is composed of much finer grained sand than the sandstones of the highest zone, and in general is much bluer in color. This is the same stratum described in the section on the western bank farther up the creek, where it is only 15 inches thick	$1\frac{3}{4}$	$41\frac{3}{4}$
2.	Remainder of the Bedford formation, 40 feet barometrically	40	40
1.	*Cleveland shale.*		

The branch that enters Bates Creek from the southeast a few rods below the highway at the mouth of which the base of the Berea sandstone is shown, has already been mentioned under the description of the Bates Creek section. This stream was followed for some distance and the following section was obtained:

Section of Southeast Branch of Bates Creek.

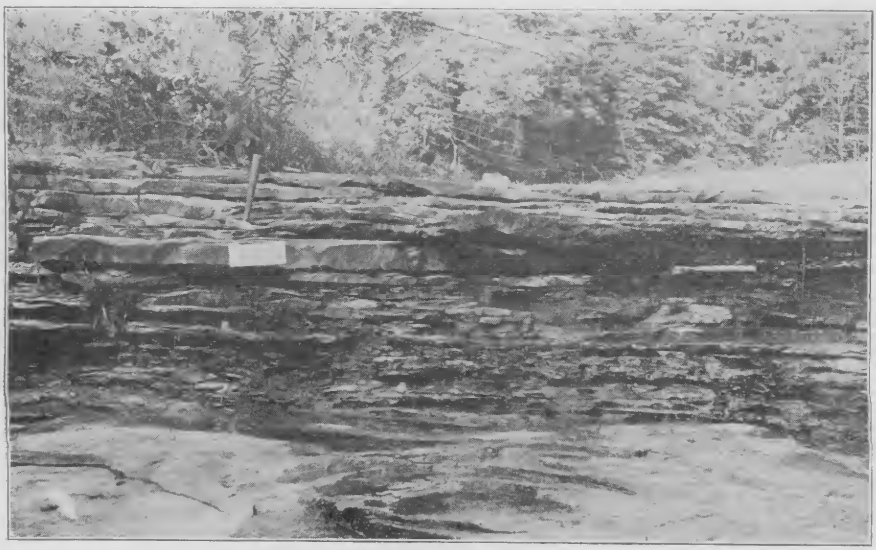
No.		Thickness. Feet.	Total thickness. Feet.
10.	*Cuyahoga terrane.* Rather numerous layers of thin, blue, laminated sandstone, which are shown well toward the top of the bank. The thickness of this zone was not determined, and it perhaps represents the *Sharpsville sandstone.* In going up this stream, the barometer made the thickness of the interval, from these sandstones down to the top of the sandstone of zone No. 3, 75 feet. On returning, however, it gave the thickness for the same interval as only 60 feet.	68±	219±
9.	Blackish shale, with no indication of sandstones; but this interval is more or less covered	25	151
8.	Apparently in place, the lowest, thin, blue, laminated sandstone. Thickness not recorded; but it is only a few inches	--	126±
7.	Blackish, argillaceous shales. The lower portion is composed of black, fissile, bituminous shale. The lowest few inches contain numerous specimens of *Lingula melie* Hall, *Orbiculoidea herzeri* Hall and Clarke, and in addition a (?) *Productella.* This portion of the shale corresponds both lithologically and paleontologically with the Sunbury	50	$125\frac{1}{2}$
6.	*Berea formation.* Upper surface is very much pitted from decomposition of iron pyrites. Fairly massive stratum of coarse-grained, quartz sandstone, which is blue, hard and much iron-stained. It makes the third fall		

No.		Thickness. Feet.	Total thickness. Feet.
	in ascending the stream, and it is believed that it constitutes the top of the Berea formation, although it is much more firmly consolidated than the Berea sandstone in general	$2\frac{1}{2}$	$75\frac{1}{2}$
5.	Shaly zone, composed largely of arenaceous shale, with a little that is argillaceous, and layers of shaly sandstone that are composed of quartz sand. The latter are generally blue, thin, irregular lenses, which are usually composed of rather coarse sand similar to that of the Berea, although some of them are rather fine-grained. Some of the shale is rather soft, argillaceous and bluish-black in color	$8\frac{1}{6}$	73 –
4.	The upper surface is rough and pitted, and forms the top of the second fall. Thin-bedded to coarser sandstone, and part of the layers show excellent ripple-marks	5	$64\frac{3}{4}$
3.	Shaly zone, composed of arenaceous shales to shaly sandstones, with argillaceous shales in the upper part	$3\frac{1}{12}$	$59\frac{3}{4}$
2.	Thin-bedded sandstones	$1\frac{2}{3}$	$56\frac{2}{3}$
1.	Top of cascade or first fall. Thicker bedded, coarse-grained, quartz sandstones. The lower portion of this zone is composed largely of thin-bedded sandstones, with some cross-bedding, and shows numerous ripple-marks. To the base of the Berea formation, where the branch enters Bates Creek	55	55

In this section the Berea formation was leveled by Mr. Morse who obtained $75\frac{1}{2}$ feet for its thickness as given above. On ascending the branch the barometer gave a thickness, from the base of the Berea formation to the top of the cascade or first fall, of 55 feet and to the top of the formation of 75 feet. The sandstone in the upper part of the Berea is dipping down the stream as noticed in its bed and this perhaps has increased the apparent thickness of the formation; but not much since in this portion the measurements were generally obtained on the banks in vertical sections. At another time the barometer gave 60 feet from the base of the formation up to the base of the shale zone, No. 5. In each instance, however, on the return trip down the stream, it gave but 60 feet from the top to the base of the formation at the mouth of the branch.

There may be a question in the above section whether the top of the Berea formation should be taken at the top of No. 4 or at the top of No. 6. The evidence upon the whole, however, seems to favor the latter and the formation has been so limited. It is perhaps possible that zone No. 5 may correspond to the Sunbury shale in the sections farther west and the overlying sandstone of zone No. 6 represent the Aurora. It is to be noted that the upper sandstone (zone No. 6) in this section and also in one to be described later in Phelps Creek at Windsor Mills, is much harder than the normal Berea; still it is composed of

A.—Anticlinal fold and overthrust fault in Bedford formation on Bates Creek, southeast of Painesville. See page 593. (Photo by Wm. C. Morse.)



B.—Disconformity between Bedford and Berea formations on Phelps Creek, southeast of Painesville. See page 599. (Photo by Wm. C. Morse.)

coarser grains of quartz sand lithologically like those of the Berea while the Aurora and Chardon sandstones are normally composed of fine, quartz sand like that of the Bedford or Sharpsville sandstones. It is also to be noted that the surface of the top layer of zone No. 4 is rough like that generally of the highest layer of the Berea formation. Still the shale of zone No. 5 does not at all resemble that of the Sunbury, while the lower part of zone No. 7 does and also contains the Sunbury fauna. It must be remembered, however, that this inarticulate Brachiopod fauna continues up into the Brecksville shale. Still the massive sandstone with pitted upper surface overlain by black, bituminous shale containing abundant specimens of *Lingula melie* Hall and *Orbiculoidea herzeri* Hall and Clarke in its basal inches is in very close agreement with the usual conditions at the contact of the Berea sandstone and Sunbury shale or Orangeville formation.

Phelps Creek Section. — The highway crosses Phelps Creek one mile northeast of where it crosses the branch of Bates Creek which has just been described. Less than one-half mile below the bridge Phelps Creek unites with Bates Creek to form Paine Creek a southern tributary of Grand River.

Section of Phelps Creek.

No.		Thickness. Feet.	Total thickness. Feet.
16.	*Berea formation.* Coarse-grained sandstone, some of it with cross-bedding and a considerable portion in thin layers. 39 feet by the barometer	39	121
15.	Shale zone, composed principally of bluish, arenaceous shale, but with some that is even argillaceous, and with very thin layers of arenaceous shale to sandstone, both containing grains of quartz sand. The whole zone is mainly a shale, and 6+ feet in thickness by hand-level	6+	82
14.	Coarse-grained sandstone, with typical appearance of the Berea; some of it shows much cross-bedding and is friable. There are also ripple-marks. Zone about 19 feet thick by the barometer, and the base of the formation forms the upper part of the small cascade, and the lower layers are rather thin-bedded. *Disconformity* well marked at the base of the Berea	19	76
13.	*Bedford formation.* On the western bank of the creek, about 90 feet below the cascade, is found, directly below the coarse-grained basal deposits of the Berea, a stratum of mainly blue, arenaceous shale	$1\frac{1}{2}$	57
12.	Zone composed mostly of two layers of blue, fine-grained sandstone, with shaly layer in the middle, varying in thickness from 9 to 10 inches	$\frac{5}{6}$	$55\frac{1}{2}$
11.	Mainly arenaceous shales, with thin layers of sandstone	1	$54\frac{2}{3}$
10.	Stratum of compact, blue sandstone, composed largely of fine grains of quartz sand. This stratum forms the		

No.		Thickness. Feet.	Total thickness. Feet.
	lower part of the small cascade and the lower portion of the section on the bank 90 feet down the stream from the cascade. It is thought that this sandstone occurs on the opposite side of the creek a few yards south of the old dam, and not far above the highway bridge, only at this point there is but a foot of it. Below it, on the bank and in the stream, the following part of the section was obtained to the base of the 10-inch sandstone at the old mill dam	$1\frac{1}{2}$	$53\frac{2}{3}$
9.	Shales, with thin layers of sandstones	4	$52\frac{1}{6}$
8.	Compact, blue sandstone	$\frac{5}{6}$	$48\frac{1}{6}$
7.	Shales, alternating with thin sandstones, and zone partly covered	$10\frac{1}{2}$	$47\frac{1}{3}$
6.	Compact, bluish sandstone, composed largely of very fine quartz grains, which is shown at the old dam	$\frac{5}{6}$	$36\frac{5}{6}$
5.	Blue shales, alternating with thin sandstones, but the shales predominating. Some of the blue sandstones have ripple-marks. The barometer made this zone 20 feet. Some rods below the bridge is a high bank on the eastern side of the creek, showing the greater part of the Bedford formation and the lower portion of the Berea, a detailed section of which will be given later	20	36
4.	*Cleveland shale.* Upper layer of black shale, 5 inches thick, which is shown just below bend in creek and high bank	$\frac{5}{12}$	16+
3.	Blue to blackish sandstone stratum, 8 inches thick, making small cascade in the creek	$\frac{2}{3}$	$15\frac{2}{3}$
2.	Black shale, like typical Cleveland, 15 feet thick by barometer	15	15
1.	*Chagrin formation.* It is shown in bed of creek, and just below is a 5-foot bank of Chagrin, with Cleveland black shale above. The Chagrin is composed of blue, arenaceous shales and thin sandstones. Some of the sandstones show ripple-marks. The barometer gave a difference of 335 feet from the top of the Chagrin in this creek down to the level of Big Creek, in Moody Hollow, near Painesville, all of which of course belongs in the Chagrin formation.		

It will assist in bringing out more clearly the very interesting character of the upper beds of the Bedford formation and the excellent examples of *disconformity* shown on Phelps Creek if two of the short sections used more or less completely in the above general section are repeated.

Section on Western Bank about 90 Feet Below Cascade.

No.		Thickness. Feet.	Total thickness. Feet.
5.	Base of *Berea sandstone,* which is rather thin-bedded.		
4.	*Bedford formation.* Mainly blue, arenaceous shale	$1\frac{1}{2}$	$4\frac{3}{4}$

No.		Thickness. Feet.	Total thickness. Feet.
3.	Zone composed of thin-layered, compact, fine-grained, blue sandstone, with shaly layer in the middle, varying in thickness from 9 to 10 inches		$3\frac{1}{4}$
2.	Mainly arenaceous shales, with thin layers of sandstone	1	$2\frac{1}{2}$
1.	Compact stratum of blue, fine-grained sandstone	1	$1\frac{1}{2}$

Seventy feet farther up the creek, on the same bank, and a little below the lowest part of the cascade all of zone No. 4 is gone and the coarse Berea sandstone rests on the thin sandstone of zone No. 3. The base of the Berea is uneven and as it is followed along the bank one can see where a thin Bedford sandstone here and there is cut away or comes in again so that the thickness of the interval from the top of the 18-inch sandstone layer to the base of the Berea is only from 16 to 17 inches instead of $3\frac{1}{4}$ feet as on the bank 70 feet farther down the stream. This shows that 23 inches of the upper portion of the Bedford formation has been removed in a horizontal distance of 70 feet.

The 18-inch sandstone stratum forms the lowest part of the cascade and on its eastern (northern) side the interval from the top of this sandstone to the base of the Berea is 1 foot 11 inches, while near the center of the cascade it is 1 foot 3 inches, showing a difference of 8 inches in that short distance. On the eastern (northern) side of the cascade there is about 1 inch of argillaceous shale with a $3\frac{1}{2}$-inch blue, compact sandstone just below. If these layers are followed toward the center of the cascade it can be seen that they are beveled off and the coarse Berea sandstone rests on their cut ends and, after their complete disappearance, even lower.

The photograph of this cascade by Mr. Morse reproduced in Plate LVI, B, shows the contact of the Bedford and Berea formations and the disconformity between them. The paper on the eastern (northern) side of the cascade marks the $3\frac{1}{2}$-inch sandstone which is cut out (the edge beveled off) toward the center of the cascade. The hammer above the paper marks the base of the Berea and the one to the right and near the center of the cascade indicates the base of the Berea where the $3\frac{1}{2}$-inch sandstone layer has all been cut away.

Some rods farther down the stream from the above sections the following one was measured from the sandstone stratum at the old dam to the top of the eastern bank a few yards to the south. This old dam and cliff is just below the house of Mr. Lewis Seeds.

No.		Thickness. Feet.	Total thickness. Feet.
7.	Coarse sandstone of *Berea*, 4 inches shown	$\frac{1}{3}$	$17\frac{1}{2}+$
6.	Layer of clay, 1 inch in thickness	$\frac{1}{12}$	$17\frac{1}{4}$
5.	*Bedford formation.* Blue, compact, fine-grained sandstone	1	$17\frac{1}{6}$
4.	Shales, with thin layers of sandstone	4	$16\frac{1}{6}$
3.	Compact, blue sandstone	$\frac{5}{6}$	$12\frac{1}{6}$
2.	Shales, with thin sandstone layers and zone partly covered.	$10\frac{1}{2}$	$11\frac{1}{3}$
1.	Compact sandstone at old mill dam	$\frac{5}{6}$	$\frac{5}{6}$

Zone No. 6 of the above section is apparently some reworked material and zone No. 5 is probably the continuation of the 18-inch sandstone noted in the cascade and the section farther down the stream (No. 1 of that section). In this latter section, however, it is 1 foot in thickness instead of 1 foot 6 inches as in the upper section, and it appears probable that its upper portion has been worn away as well as the higher zones of the Bedford shown in the section farther up the creek.

As has been mentioned above there is a high bank on the eastern side of the creek some rods below the highway bridge which shows the greater part of the Bedford formation together with the lower portion of the Berea. From the top of the Cleveland shale, which is shown in the bed as well as on the bank of the creek only a short distance below its bend, up the bank to the base of the Berea has been leveled by both Mr. Morse and the writer at different times, with the following results:

Section of High Bank on Phelps Creek.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Berea sandstone.* Coarse-grained sandstone.		
4.	*Bedford formation.* Blue shale was seen within a few inches of the lowest exposures of the Berea sandstone. The zone is apparently composed of shale and sandstone; although it is more or less covered on that part of the cliff which is accessible for examination. The writer obtained 8 feet for the thickness of this interval, and Mr. Morse 9½ feet	8	41
3.	Blue, fine-grained sandstone, which is much shattered where examined on the bank; but looks massive in the face of the nearly vertical cliff	1	33
2.	Bluish, argillaceous and arenaceous shales, with thin layers of sandstone, an occasional one 6 inches thick, especially in the upper third of this zone, where they occur most frequently. The steep bank does not extend clear to the base of the formation; but it is reached a few rods farther down stream. Mr. Morse obtained 32 feet for the thickness of this zone, while the writer, by level, obtained 37 feet, and by barometer 35 feet. In this section, the lowest measurement is taken in order that there may be no question but that the thickness of the Bedford formation in this section is at least as great as stated	32	32
1.	*Cleveland shale.*		

The above section shows that the thickness of the Bedford formation on Phelps Creek, where at one locality nearly its complete thickness is shown on an almost vertical cliff, is at least 41 feet, and perhaps it is as much as 46 feet or a little more. The similar high bank on Bates Creek, three-fourths of a mile to the southwest, gives 49¾ feet for the thickness of the Bedford at that locality.

In the above section the writer is not certain that the 1-foot sandstone in the upper part of the Bedford as shown on the cliff (No. 3) is identical with the one at the old dam above the highway bridge (No. 1 of that section and 10 inches thick). If they are identical, as the appearance seems to indicate, then these two sections will give a thickness of rather more than 49 to 54 feet for the Bedford formation on Phelps Creek. Again, if these two sandstones just mentioned are identical then in the general section of Phelps Creek the 20 feet obtained by the barometer for the interval from the sandstone at the old mill dam to the base of the Bedford is too small, and that interval should be considered as ranging in thickness from 32 to 37 feet. If this change be made in that section then the thickness of the Bedford formation will become considerably greater than the 41 feet there given, varying from at least 53 feet up to 58 feet or more.

The above section is an interesting one in several respects, and in review attention will now be called to the most important points. The shale zone of 6 or more feet below the middle of the Berea is an interesting lithologic phase of this formation, and recalls the similar zones near the top of the formation already described in Stebbins Gulch and on the branch of Bates Creek, about a mile to the southwest of the present section. The section, which is mostly barometric, however, gives a thickness of 64 feet for the Berea formation without reaching its top.

The contact between the Bedford and Berea formations is very interesting and shows conclusively the *uneven* surface on which the Berea sandstone is deposited. As has been described, the shale zone, No. 13 of the general section, 1 foot 6 inches in thickness, that occurs at one point on the western bank between a 10-inch sandstone zone and the base of the Berea, only 70 feet farther up the creek is completely gone so that the Berea rests directly on the sandstone zone of No. 12. Again in the small cascade, just above the two sections already mentioned in this paragraph, the contact of the two formations occurs. When this is examined it will be seen that near the eastern (northern) bank just below the Berea sandstone is first an inch of shale below which is a 3½-inch compact sandstone. As the line of contact is followed toward the center of the cascade it will be seen that these two layers are beveled off and the Berea sandstone rests lower and lower on them until finally they are completely gone and its base is below their horizon. It appears to the writer that these sections clearly show a *disconformity* at the contact of the Bedford and Berea formations.

The creek also affords an opportunity for measuring the complete thickness of the Bedford formation which on the high cliff below the bridge is apparently from 41 to 46 feet. It also appears probable that farther up the stream more of the upper portion of the Bedford formation is retained, so if that be taken for its upper portion in this section then

the thickness of the formation will become as great as from 53 to 58 feet or more.

The 8-inch stratum of dark colored sandstone 5 inches below the top of the Cleveland black shale is an interesting lithologic phase in that formation, which in this glen is some 16 feet in thickness.

Section on Branch of Paine Creek.—Paine Creek is formed by the union of Bates and Phelps creeks, and on a western branch of it where crossed by the highway about 1 mile east of Hillhouse postoffice, an interesting section was studied. This locality is in LeRoy Township about 1½ miles northwest of the bridge over Phelps Creek and 1¾ miles from the base of the Berea sandstone on Bates Creek where the eastern branch enters it.

The Cleveland black shale is shown by the side of the highway on each side of this stream; but the better exposure is on the eastern side near the top of the small hill on the highway. The barometer was read at the level of Big Creek in Moody Hollow and it gave the base of the Cleveland shale at this locality as 385 feet higher, all of which is in the Chagrin formation. By the side of the highway to the east of the run is a small anticlinal fold where probably the entire thickness of the Cleveland shale, with the basal part of the Bedford formation, is shown. The section at this point is as follows:

Section on Bank above Highway, One Mile East of Hillhouse.

No.		Thickness. Feet.	Total thickness. Feet.
9.	*Bedford formation.* As weathered, buff, argillaceous and arenaceous shale, with two layers of thin sandstone, the lower one an inch, the upper 2 inches or more in thickness. In the very base of the shale are fossils as *Camarotœchia*	2½	21½
8.	*Cleveland formation.* Black, bituminous shale about an inch in thickness at the very top	$\frac{1}{12}\pm$	19—
7.	Fine-grained, dark gray to blackish sandstone, 7½ inches thick	$\frac{7}{12}+$	$18\frac{5}{6}+$
6.	Black, bituminous shale, with numerous specimens of *Lingula*	$\frac{1}{6}$	18¼
5.	Bluish to buff, argillaceous shale	⅓	$18\frac{1}{12}$
4.	Black, bituminous shale	¼	17¾
3.	Gray, argillaceous shale	½	17½
2.	Black, bituminous shale, as shown on the bank, with an occasional somewhat sandy layer. Probably the base of the Cleveland shale	15½	17
1.	In the road gutter, bluish to gray, softer shale than above, with some bands that are black, tough, and bituminous	1½	1½

In the above section the Cleveland shale has a thickness of about 17½ feet while on Phelps Creek about 1½ miles to the southeast 16+

feet was obtained. It is also interesting to note a sandstone stratum almost at the top of the formation in both of these sections. In the latter one with a thickness of $7\frac{1}{2}$ inches with only 1 inch of black, bituminous shale above and on Phelps Creek a similar sandstone layer 8 inches thick with 5 inches of black shale above.

Another section in a small gully below the highway at this same locality was also measured in which the top of the Cleveland shale is not shown, the exposures ceasing before reaching the sandstone stratum almost at its top.

Section on Bank below Highway One Mile East of Hillhouse.

No.		Thickness. Feet.	Total thickness. Feet.
14.	*Cleveland formation.* Softer shale than that below, 3 inches of which is shown at the top of the section. This zone probably corresponds to the 6-inch one of gray, argillaceous shale (No. 3) in the section above the highway	$\frac{1}{4}$	37 –
13.	Black shale	$1\frac{5}{6}$	$36\frac{2}{3}$
12.	Sandy layer	$\frac{1}{6}$	$34\frac{5}{6}$
11.	Black, bituminous shale	11	$34\frac{2}{3}$
10.	Blue, thin sandstone, with blue shale in the middle	$\frac{2}{3}$	$23\frac{2}{3}$
9.	Black shale, about 5 inches shown	$\frac{5}{12}$	23
8.	Bluish-gray, sandy shale, from one-half to three-fourths of an inch shown	$\frac{1}{16}$	$22\frac{7}{12}$ –
7.	Black, compact, bituminous shale	$1\frac{1}{2}$	$22\frac{1}{2}$
6.	*Chagrin formation.* Bluish, arenaceous shale, $5\frac{1}{2}$ inches thick	$\frac{5}{12}$ +	21 –
5.	Bluish, shaly sandstone	$\frac{1}{4}$ ±	$20\frac{1}{2}$
4.	Bluish, arenaceous shales, with fossils as *Camarotœchia*	$1\frac{1}{6}$	$20\frac{1}{4}$
3.	Bluish, shaly sandstone	$\frac{1}{2}$	$19\frac{1}{12}$
2.	Partly covered slope from gully to stream	$17\frac{3}{4}$	$18\frac{7}{12}$
1.	Bluish sandstone in run at foot of hill	$\frac{5}{6}$	$\frac{5}{6}$

In the above section the top of the Cleveland formation is not shown; but if the opinion be correct that its highest zone (No. 14) corresponds to zone No. 3 of the section above the highway, and the thickness of the overlying zones be added to the 15 feet 11 inches shown in it, then the thickness of the formation will be $17\frac{3}{4}$ feet. The Cleveland shale is shown on the upper part of the bank for some rods down stream; but its limits are not sharply defined, especially the upper one.

Madison Township.—The Grand River flows across the southern part of Madison Township in a nearly westerly course. About two miles south of Madison Village is an iron highway bridge across the river near the Grand River Mill. Above the bridge is a steep bank of the Chagrin shale, perhaps 80 feet high. The rocks are mainly bluish to grayish argillaceous shales; but with some arenaceous layers

which weather to a brownish or rusty color. There are also layers of thin grayish to bluish-gray sandstone, some of which show numerous marks which have generally been regarded as of fucoidal origin although perhaps they were made by marine worms, and in addition there are layers that are somewhat calcareous. The rocks contain a few fossils which are apparently mainly confined to the arenaceous shales, although occasionally one is found in the thin sandstones. The only species noted are *Liorhynchus ohioense* (?) which possibly are young specimens of *L. mesicostale*; but they appear to the writer to be small and probably young specimens of the new species described from this formation. A broken specimen of *L. globuliforme* Van. var. *chagrinanum*, which is common in certain outcrops south of this locality toward Thompson, and very poorly preserved specimens of (?) *Glossites* sp. or perhaps *Modiomorpha* sp. were found. The dip at this locality along a line S. 30° E. is $2\frac{1}{2}$ feet in a horizontal distance of 180 feet, or 1 foot in 72, which is at the rate of 73 feet per mile. A little below the bridge is another shale bank apparently more than 100 feet in height.

In the gutter by the roadside on the highway from Madison to Thompson Ledge, just below the house of Mr. Stearns, 3 miles south of Madison are blocks of shaly sandstone which contain a considerable number of fossils. The sandstone is grayish weathering to a rusty color and occurring in blocks which split into somewhat shaly layers. Part of the blocks contain numerous specimens of two or three species and the fossils are as abundant as in some of the New York Chemung sandstones. The number of species, however, is not large, as will be seen from the accompanying list; but it is one of the best localities for collecting in the Chagrin formation that was noted in Lake and Geauga counties. The barometer, with an interval of 1 hour and 10 minutes between the readings, made this locality 305 feet higher than the bed of Grand River at the iron bridge, one mile to the north, and it is apparently near the top of the Chagrin formation. The following species were collected at this locality:

1. Spirifer disjunctus Sowb. -- (c)
   Compared with authentic specimens of this species at Cornell University.
2. Cyrtia alta Hall -- (c)
   These specimens were compared with others at Cornell University, from Sherman, Chautauqua County, N.Y., which had been identified as this species by Professor Williams. The Sherman specimens of this species were associated with a good many other specimens of *Spirifer disjunctus* Sowb., which had also been identified by Professor Williams, and Camarotœchias. Some of the Sherman specimens of *C. alta* have strong horizontal ridges and furrows on the hinge area of the ventral valve, as is faintly shown on these Ohio specimens; but the vertical lines are better shown on the latter. A few of the Ohio specimens

show the grooves in the margins of the deltidial fissure as described by Hall. Specimens from Meadville, Pa., the locality from which the types described by Hall came, are practically identical with those south of Madison, Ohio.

At the New York State Museum, the two original specimens represented by figs. 6-8, on pl. 43, Vol. IV, Pal. N. Y., were studied, which show the cardinal area of the ventral valve, and there is no particular difference between them and similar specimens from this locality. This is especially true of a specimen from this road showing the groove on each side of the deltidial fissure, and the Ohio specimens have fully as high hinge area as any of the types from Meadville, Pa. The original of fig. 2, pl. 43, is also in the State Museum, which is a dorsal valve that shows obscure plications on the fold. The Ohio specimens agree closely in all essential characters with the type ones of this species, and there is no question as to the correctness of this identification. Most of the Meadville type specimens are in blocks of brownish, weathered sandstone, which contain large numbers of fossils. There are, however, only a few species which are mainly:

Cyrtia alta Hall
Spirifer disjunctus Sowb.
Athyris sp.
Schuchertella chemungensis (Con.) Girty
Reticularia præmatura (Hall) Schuchert

Hall reported the types of this species as from the Chemung of Meadville, Pa., and Schuchert, in 1890, gave it as from the Chemung of Meadville and Union City, etc., Pa., and "top of the Erie shale at Bedford, Ohio, associated with *Spirifer disjunctus*."[1] In this paper it is referred to the genus *Syringothyris*; but in 1897, Professor Schuchert followed Hall and Clarke, who had referred it to the genus *Cyrtia*[2], although he gave its geological horizon as the Waverly, an opinion that has been accepted by Grabau and Shimer.[3] Specimens in the National Museum (No. 33,639) from the Chemung, near Union City, Pa., are labeled as this species. If there is any question concerning the age of the beds near Meadville, Pa., that have been referred to the Chemung by Professors Hall and I. C. White, such query cannot be raised concerning those of Sherman, Chautauqua County, N.Y., which are in the typical Chemung of southwestern New York. The evidence, in the writer's judgment, supports the opinion that this species is a Chemung, rather than a Waverly one.

3. Camarotœchia orbicularis Hall ------------------------------- (a)

These specimens have the orbicular shape of this species, 18 to 22 plications, with 4 on the mesial fold and 3 or 4 in the

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[1]Ninth Ann. Rept. State Geologist [N. Y.], p. 36.
[2]Bull. U. S. Geol. Survey, No. 87, p. 196.
[3]North Am. Index Fossils, Vol. I, 1907, p. 314.

sinus. The Ohio specimens were compared with types of this species in the New York State Museum. The original of fig. 40, pl. 55, Vol. IV, Pal. N. Y., from Meadville, Pa., is a dorsal valve, which is much more gibbous (thicker) than the figure indicates. This specimen has 4 strong plications on the fold, with a fainter one on the right side, while on the left side are 8 distinct plications, with a faint one toward the margin. The type specimen of a dorsal valve from Olean, N. Y. (fig. 41, pl. 55), has 4 strong plications on the medial fold and 6 on each side, or 16 in all, as is very well shown on the figure. The original of fig. 46, which is from Meadville, Pa., has only 6 plications on each side. A ventral valve on the same block has 3 strong plications in the sinus, 1 on each side intermediate between the sinus and lateral margin, and 5 on each margin, making 15 in all. Another dorsal valve from Meadville has 4 plications on the fold and 6 or 7 on each side, making 16 or 18 in all. Hall's statement that this species is marked by about 24 or more ribs, appears to call for too many. A dorsal valve from the Madison road has 4 strong plications on the median fold, with 1 faint one on the right side and 8 plications on each side, making 21 in all. This specimen is very similar to the type from Meadville, Pa. (fig. 40 of pl. 55), except that it is not so gibbous. This Meadville specimen is $\frac{12}{16}$ inches in length and $\frac{14}{16}$ inches in width; while the Madison road one is $\frac{11}{16}$ inches long and $\frac{13}{61}$ inches wide. The strength or coarseness of the plications is about the same on the Ohio specimens and those from Meadville and the similarity of the dorsal valves is very marked. The plications on most of the Ohio specimens are rounded and in general there does not appear to be more than 20 clearly defined ones on either of those from Meadville or Ohio.

In the American Museum are the originals of figs. 43-45 of pl. 55; figs. 43 and 44 are internal impressions from Meadville, Pa., and fig. 45 represents an internal impression of a dorsal valve from near Howard, Chautauqua County, N.Y. This latter specimen has a median septum, 4 plications on the fold and 9 on the right side, with an additional faint one near the cardinal margin. The left side is not so well preserved and shows only 8 plications. The drawing is not very accurate so far as the number of plications is concerned. The two Meadville specimens show 4 plications on the fold, 3 in the sinus of the original of fig. 43, 3 distinct ones with an additional one on the side of the sinus of the specimen represented by fig. 44, and with 6 or 7 between the fold or sinus and lateral margin. There appears to be no question concerning the identification of the Ohio forms with this species. Associated with the type specimen of this species at Olean, N. Y., are numerous specimens of *Spirifer disjunctus* Sowb., and with the Meadville types numerous ones of *S. disjunctus* Sowb., together with

others of *Atrypa spinosa* Hall (?) and *Orthis* sp. The National Museum contains specimens from LeBoeuf, Pa. (No. 16,732), labeled *Camarotœchia orbicularis* Hall, Chemung, which are very similar to some of the Ohio ones. Others, so labeled (No. 33,637), are from 4 miles northwest of Union City, Pa. This species is given by Professor Schuchert as only in the Chemung and the localities mentioned are Chautauqua County, N. Y., and Meadville, Pa.,[1] and Hall's statement was that it is found in the higher beds of the Chemung at the above named localities.

4. Camarotœchia stephani Hall.................................. (rr)

There are two specimens from this locality that agree closely with some of the types of this species which are in the American Museum, and also with specimens in the same museum from Meadville, Pa., which were so identified by Hall.

5. Liorhynchus globuliforme Van. var. chagrinanum n. var. .... (a)

Specimens of this species have probably been reported in Ohio lists of fossils as *L. mesicostale* Hall. The specimens are gibbous, medial fold and sinus marked by rather coarse and generally rounded plications of which there are 3–5 in the sinus and 4–6 on the fold, with faint ones on the lateral slopes. An average specimen is 25.8 mm. long and 24.4 mm. wide. A specimen somewhat crushed along the sides is 23.5 mm. long, 19 mm. wide and 20 mm. thick. A broad and large one is 30 mm. long and 29 mm. wide, while another, which does not show the entire length, is 22 mm. long and 25 mm. wide. The figure (24, pl. 57, Vol. IV, Pal., N.Y.) of a narrow form of *L. mesicostale* Hall is 28.4 mm. long and 27.2 mm. wide; while a broad form (fig. 23) is 25.7 mm. long and 33.5 mm. wide, and fig. 20, which is said to be a large individual, is 14.4 mm. thick. Figure 26 of *L. globuliforme* Van., is 21.8 mm. long and 21.7 mm. wide (having almost identical length and breadth); while fig. 27 is 24.1 mm. long and 21.2 mm. wide. Figure 28 gives a side view of one valve of this latter species which is 23.8 mm. long and 10.3 mm. thick, indicating a thickness of 20.6 mm. for the entire shell. In proportions there is not a very marked difference between the narrow form of *L. mesicostale* and *L. globuliforme*, except in the *thickness*, and in this the Ohio specimens agree with *L. globuliforme*. In general the other proportions of most specimens are fully as near or nearer those of *L. globuliforme*.

These specimens were compared with authentic ones of *L. mesicostale* from the Ithaca formation at Ithaca, in the Cornell collection, and a somewhat general agreement noted. The Ithaca specimens, as a rule, are badly crushed, and are rather flat, while the Ohio ones are strongly gibbous. The 4–6 strong plications on the medial part of the shells, and their general absence on the

[1]Bull. U. S. Geol. Survey, No. 87, p. 167.

sides, were in agreement. Specimens from Port Crane, N. Y., identified by Professor Williams as *L. globuliforme*, appeared to be narrower in proportion to their length than these from Ohio. Still Professor Williams said that the Ohio specimens suggest *L. globuliforme*, although they differ in some respects.

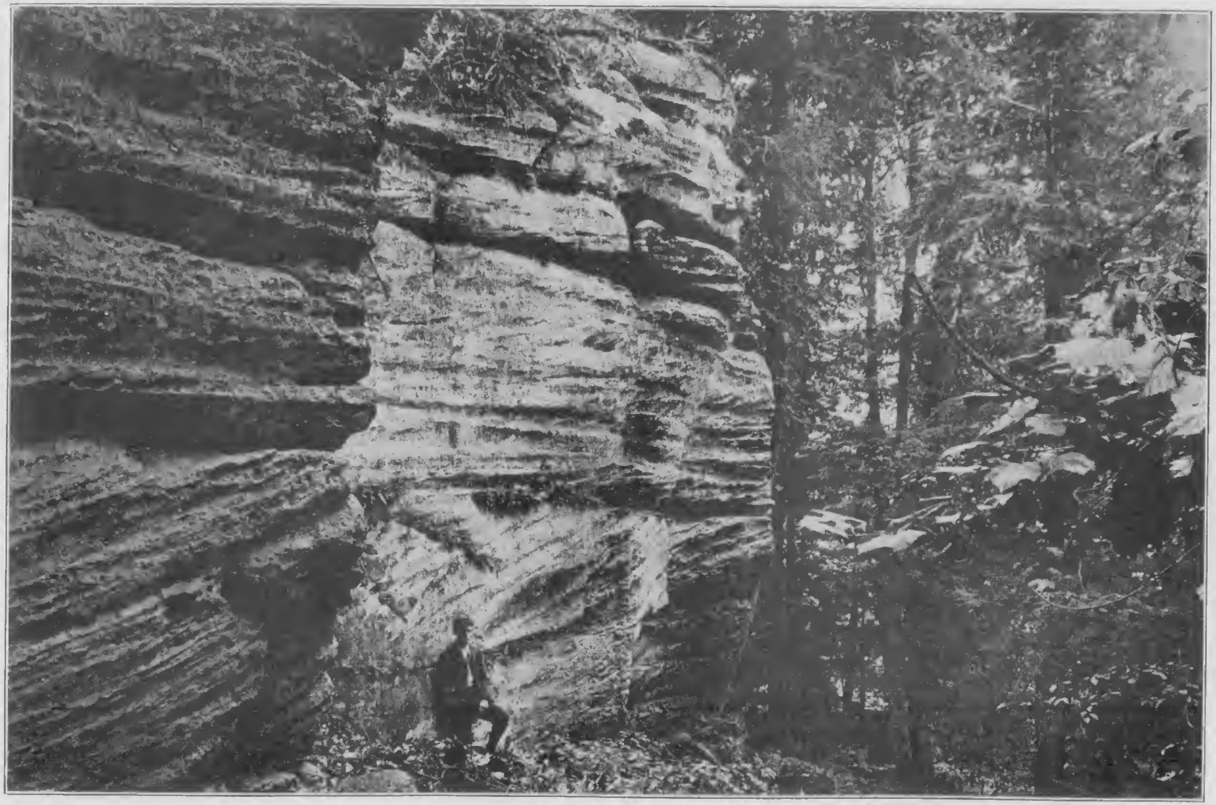
The originals of figs. 27 and 29, pl. 57, Vol. IV, Pal. N. Y., are in the New York State Museum, and the Ohio specimens resemble them in narrowness, although some of them are about, or fully, as broad as narrow specimens of *L. mesacostale*, and they have rather more plications than *L. globuliforme*.

The original of fig. 26, pl. 57 of *L. globuliforme* from Cortland County, N. Y., is in the American Museum (No. $\frac{6039}{1}$), which has 5 rather broad plications on the fold, with 2 or 3 rather indistinct ones on the sides. The Madison road specimens agree more closely with this type specimen than with the originals of figs. 23 and 25 of *L. mesicostale*, probably from Tompkins County, N. Y., which are also in the American Museum. These gibbous Ohio specimens were examined by Professor Whitfield who considered them as *L. globuliforme*. He could not see a median septum on the Ohio forms; but it appears to the writer that certain specimens show a distinct one. There are, however, some rather slight differences between these and the type of *L. globuliforme*. Consequently, the Ohio specimens have been given a varietal name referring to their occurrence in the Chagrin formation. This species was given by Hall as in the Chemung in the southern part of Otsego County, and elsewhere in southeastern New York. In Vol. VIII, pt. II, Pal. N. Y., pl. 59, explanation of fig. 23 of this species, that specimen is given as from the Hamilton of Otsego County, N. Y., but the name of the formation is perhaps in error, and the specimen of fig. 25 is reported as from the Black shale (Genesee shales) of Lexington, Indiana.

6. Athyris polita Hall -- (r)

Thompson Ledge and Vicinity. — Thompson Ledge is a conspicuous outcrop of the Sharon conglomerate near the central part of Thompson Township. It underlies this portion of the township, which reaches an altitude of 1,300 feet above sea level, and the ledge is the most northern outcrop of the Sharon conglomerate in the State. From the central part of the township which forms a small plateau there is a rapid slope to the west, north and east. From the northern end of the ledge and plateau there is a beautiful view of the country sloping toward Lake Erie, which on a clear day is faintly visible some ten miles away. The view is one of the best to be found in northern Ohio and for many years it has been a popular resort for picnics and excursions. Its distance of six miles or more, however, from the nearest steam or electric road prevents many people from visiting it.

PLATE LVII.



Sharon conglomerate of Thompson Ledge showing Cross-bedding and differential weathering. See page 609.

The top of the ledge according to the barometer is some 620 feet higher than the bed of the Grand River at the iron bridge on the Madison-Thompson highway, but on the topographic map it is apparently 580 feet. The cliff in the vicinity of the Devil's Lane is 38 feet high and at another place 48 feet of conglomerate is shown in the ledge. A resident of that neighborhood told the writer that he thought there was about 20 feet more of the conglomerate below the base of the ledge. A well was sunk by Patrick Sullivan on the plateau which went to a depth of 63 feet without reaching the bottom of the conglomerate. The owner of the Ledge House told the writer that the well on top of the conglomerate a few yards back of the hotel, which furnishes excellent water, is 50 feet deep and that wells on the plateau show that the conglomerate is about 80 feet thick. The conglomerate is finely shown in the ledge and at various places on the plateau near Thompson, so that this is an excellent locality for studying it. The cliff near this lane shows 38 feet of the conglomerate, which is very pebbly, the abundant pebbles extending from the very bottom to the top of the ledge. The face of the cliff also shows excellent examples of cross-bedding and differential weathering as may be seen in Plate LVII, where a portion of the face of the ledge is shown. Farther along in the same zone the oblique layers of pebbles are less inclined and finally they become horizontal. The cross-bedded zone is limited above and below by horizontally bedded zones and its thickness varies a little; but the average is about 5½ feet. The conspicuous pebbles do not run all the way through the conglomerate, but occur more or less in zones. Toward the upper part of the cliff the pebbles are very thick. Portions of the face of the cliff are roughened and pitted as shown in Plate LVII, apparently caused by unequal hardness of the cementing material; this is an example of *differential weathering*. The pebbles are practically all quartz, mostly white; but with an occasional one of rose color and also of smoky quartz. Where these pebbles in such large quantities came from is a problem, since there are none of the older formations, at least within easy distance of this one, that could have furnished them. There are occasional conspicuous joints in the cliff, one of which known as the Devil's Lane and shown in Plate LVIII, affords a means of passage from the bottom to the top of the cliff. The dip on some layers is in about the direction of S. 10° W.; but it varies greatly. The conglomerate has been quarried in a rather small way in some parts of the ledge and used mainly for bridge abutments.

To the west of Thompson and the Telephone road the conglomerate is not so pebbly as in the main ledge described above. The outcrops show a coarse-grained sandstone containing an occasional pebble. These outcrops are in the lower part of the conglomerate and not improbably are stratigraphically lower than those seen in the main ledge to the east. Excellent glacial striæ are seen by the side of the road just north of

Thompson. The most conspicuous set of striæ run N. 48° E. and lighter ones N. 18° E.

On the Telephone road from Thompson to Madison are occasional outcrops of rocks. At one locality but a short distance above the lane leading to the house of A. L. Williams, and barometrically 290 feet higher than the bed of the Grand River at the iron bridge, is a zone of shaly sandstone. The sandstones are thin, rather irregular and of grayish to greenish-gray color. Below them are grayish and greenish argillaceous shales with some bands that are very rusty when weathered. Some of the thicker and smoother layers of the thin-bedded, greenish-gray sandstones have ripple-marks. The sandstones are rather fossiliferous, containing numerous specimens of *Spirifer disjunctus* Sowb., *Camarotœchia orbicularis* Hall and *Liorhynchus globuliforme* Van. var. *chagrinanum*. These rocks all came from the gutters by the roadside between the mail boxes for A. L. and C. A. Williams. The zone apparently corresponds with the one described on the Thompson road to the east and belongs in the upper part of the Chagrin formation. The complete list of fossils collected at this locality is as follows:

1. Spirifer disjunctus Sowb. -- (c)
2. Camarotœchia orbicularis Hall -------------------------------- (c)

   Specimens from this locality were compared with types of this species in both the New York State and American Museums. In number of plications they agree well with the original of fig. 41, pl. 55, Vol. IV, Pal. N. Y., from Olean, N. Y., which is in the State Museum. This specimen has 4 plications on the fold and 6 on each side; while a specimen on the same block with the original of fig. 46, from Meadville, Pa., has 4 on the fold and 7 or 8 on each side. These type specimens, however, are more gibbous than those from this locality which are in part from arenacous shales or shaly sandstones and probably are somewhat flattened by pressure. The specimens from this locality are rather smaller than the majority of this species, although not smaller than the originals of figs. 43 and 44 of pl. 55, which are in the American Museum. The largest from this locality certainly appear to belong to this species; but associated with them are smaller ones, whose specific reference is more uncertain.
3. Camarotœchia stephani Hall ---------------------------------- (r)

   These specimens are rather elongate, and one has 3 plications in the sinus and 7 on the side. This specimen agrees fairly closely with the original of fig. 10, pl. 55, Vol. IV, Pal. N. Y., from Cortland County, N. Y., which is in the American Museum. This type is an internal impression of a ventral valve, which has 3 rather broad plications in the sinus, with about 9 on the right side. The left side is covered, although it is not so shown in the figure. This specimen is more angular than type specimens of *C. eximia* Hall from Ithaca of about the same size and the plications are slightly broader. The differences, however, between the types of the two species are rather

Joint in Sharon conglomerate at Thompson Ledge. See page 609.

slight, and one might easily doubt to which one small and imperfect forms would better be referred. There are specimens in the American Museum from Meadville, Pa., identified by Hall as *C. stephani*, that are associated on the same blocks with others of *Spirifer disjunctus* Sowb. These specimens have 3 plications in the sinus and from 5 to 8 on each side. Another one from the vicinity of Mansfield, Tioga County, Pa., has 3 plications in the sinus and 8 on each side. It will be seen that these authentic specimens including the type represented by fig. 10 have from 13 to 21 plications on a valve. Hall gave in his specific description from 28-32, while the Ohio specimen from this locality has 17 and the more angular outline of *C. stephani*. It appears safe to refer this specimen and some others to this species.

4. Camarotœchia cf. eximia Hall ---------------------------------- (r)
   Certain specimens approach the form of *C. eximia* and have the rather fine, angular plications of that species.
5. Liorhynchus globuliforme Van. var. chagrinanum n. Var.-------- (c)
   These specimens were compared with the types of *L. globuliforme* in the New York State and American museums.
6. Cyrtia alta Hall -- (rr)
   The specimens were compared with authentic ones of this species at Cornell and types in the New York State Museum. One shows the grooves along the sides of the deltidial fissure.
7. Reticularia præmatura (Hall) Schuchert--------------------- (r)
   Specimens compared with authentic ones of this species at Cornell and with types in the New York State Museum.
8. Athyris polita Hall -- (r)
   These specimens were compared with types of this species in the New York State Museum and there are external impressions of two ventral valves which clearly belong to it. Associated with them are two specimens of dorsal valves which are rather broader than typical specimens of this species, although they probably belong to it.
9. Productella hirsuta Hall (?) ---------------------------------- (r)
   These specimens were compared with *P. hirsuta* Hall and *P. lachrymosa* (Con.) Hall, at Cornell, and the small pustules and general appearance seem to refer them to the first named species.
10. Pelecypod (winged shell) ------------------------------------ (rr)
11. Turrilepas (?) newberryi (Whitf.) Clarke (?)------------------ (rr)
   Whitfield gave the formation and locality of this species as the Cleveland shale, Sheffield and Birmingham, Erie County, Ohio.

As already stated the horizon from which the fossils were collected on the two roads from Madison to Thompson is near the top of the Chagrin formation. From the notes accompanying lists of Chagrin fossils appearing in earlier portions of this bulletin it will be seen that the majority of those identified from these two localities are from rocks that have generally been considered as Chemung. A part of them occur at localities in southern or southwestern New York which are almost within the typical region of the Chemung formation, or else the stratigraphy

is so clear that there can be no doubt that the rocks are of equivalent age. It is also interesting to note the agreement between this fauna and the one near Meadville, Pa., which furnished Professor Hall several new species and which he considered as also of Chemung age. Species of this fauna, a part or all of the type specimens of which came from Meadville, that have been identified at one or both of these Madison localities, are as follows:

1. Cyrtia alta Hall.
2. Camarotœchia orbicularis Hall.
3. Reticularia præmatura (Hall) Schuchert.

The number of species common to the upper Chagrin of eastern Ohio and the Meadville fauna will be increased from the additional lists of Chagrin fossils collected at still more eastern localities in Ohio.

The age of the rocks containing the above species was still considered Chemung by Hall and Clarke when their work on the Genera of the Palæozoic Brachiopoda was published in 1894. In this standard monograph *Cyrtia alta* is given as from the Chemung on p. 42 and explanation of pl. 26, pt. II, Vol. VIII, Pal. N. Y.; the same formation is given for *Camarotœchia orbicularis* on p. 192 and explanation of pl. 57; and the same statement for *Spirifer* [*Reticularia*] *præmatura* on p. 37 and explanation of pl. 36. Professor Schuchert in his Synopsis of Am. Fossil Brachiopoda (Bull. U. S. Geol. Survey, No. 87, 1897) gave *Cyrtia alta* as from the Waverly of Meadville, Pa., and Bedford, Ohio; *Camarotœchia orbicularis* from the Chemung of Chautauqua County, N. Y., and Meadville, Pa.; and *Reticularia præmatura* from the Chemung of Meadville and Oil Creek, Pa. At an earlier date Professor Schuchert gave *Syringothyris* [*Cyrtia*] *alta* as from the Chemung of Meadville and Union City, Pa., and Erie shale at Bedford, Ohio,[1] and the reason for the change to Waverly in the later work is not obvious, since the other two species which both occur at Meadville, Pa. are left in the Chemung. The geology of Crawford County, Pa., of which Meadville is the county seat, was described by Dr. I. C. White and the fossils from near that city described by Professor Hall probably came from the Venango oil sand group which Dr. White regarded as upper Chemung.[2] Professor Williams in his paper on the shifting of faunas states that in the Meadville section "the Chemung species have not been discovered higher than the Riceville shales [the formation overlying the Venango oil sands], above which the Waverly fauna comes in in its purity."[3] On the Meadville section as shown on his "Comparative Chart of Devonian Sections" the dotted line 4 representing the lower limit of the Waverly faunas apparently separates the Venango and Riceville formations.[4]

In the gutter of the highway barometerically 65 feet higher than

[1]Ninth Ann. Rept. State Geol. [N. Y.], 1890, p. 36.

[2]2d Geol. Survey Pa. Q^4, 1881, p. 117, f. n. Also see the description of outcrops of the Venango upper sand at Meadville on p. 102 and species of fossils given on p. 171.

[3]Bull. Geol. Soc. America, Vol. 14, 1903, p. 184.

[4]Ibid., pl. 16 and see p. 180 for explanation of numbered lines. This chart is pl. I, Bull. U. S. Geol. Survey, No. 210, and the explanation is on p. 121.

the fossiliferous zone described above, below the house of Mr. C. Mosley, is the lowest outcrop of coarse-grained, friable buff to brownish-gray sandstone. This is considered the Berea grit; some of the layers have ripple-marks and the barometer gave a thickness of 55 feet for these sandstones as shown on the highway. In a small run in the woods east of the road are exposures of the Berea sandstone where it has been explored to a small extent for quarrying. Slabs of the upper sandstone have been dug up and it is probably one of the small quarries mentioned by Read to the north of Thompson Ledge.[1] The barometer made the top of the exposures in the woods 5 feet higher than the highest outcrops seen by the roadside, which indicates a total thickness of 60 feet for the Berea formation on the northern approach to Thompson Ledge.

The outcrops of the Cuyahoga terrane are few and inconspicuous on this road and its thickness was not determined with any degree of exactness. The readings of the barometer on two days differed markedly; but indicated a thickness of between about 100 and 150 feet for the Cuyahoga terrane.

At the four corners about one-fourth mile east of Thompson Ledge are drab to bluish soft argillaceous shales exposed in the banks and gutters of the roads which evidently belong in the Orangeville shale. These corners are by the barometer 140 feet lower than the top of Thompson Ledge or perhaps about 75 feet below the base of the conglomerate. Down a run from the four corners and 20 feet lower are loose pieces of fine black shale. Ten feet lower, however, on the bank of the run is an exposure of about 3 feet of blue argillaceous shale belonging in the Orangeville. In the gutter by the roadside, on the road leading east from the four corners and 40 feet lower by the barometer, are blue argillaceous shales. A little higher by the roadside some of the shale is blackish; but it all belongs in the Orangeville.

Forty-five feet lower by the barometer are coarse-grained, soft, buff-colored sandstones of the Berea considerably broken up as they appear in the road gutter; the thickness of the formation was not determined. The country at this horizon shows a flat terrace due to the presence of the Berea grit. Thirty-five feet lower than the base of the preceding zone are fine-grained and rather buff sandstones in the road gutter; while below are soft, olive, argillaceous shales. These shales are probably in the Bedford formation and perhaps the superjacent sandstones.

Near South Thompson, 2½ miles south of Thompson and 60 feet lower, is the Spring Pond which is formed by a large spring that issues from about the base of the Sharon conglomerate. It forms a brook of considerable size which has been dammed, thereby making an excellent fish pond, below which is the Vogel spring mill. About this escarpment there are numerous good springs at the base of the Sharon conglomerate and the Berea grit as is to be expected where porous rocks

[1] Geol. Surv. Ohio, Vol. I, 1873, p. 524.

rest upon argillaceous shales. Some years ago a well was drilled at South Thompson which is reported to have obtained some oil in the Berea grit and to have gone to a depth of 1,000 feet. The first small glen south of Montville, which is about $2\frac{3}{4}$ miles south of South Thompson, shows ledges of Sharon conglomerate.

Nelson Ledge.—From Thompson Ledge the eastern outcrop of the Sharon conglomerate in general follows a nearly north and south line, with certain indentations caused by the headwaters of various streams, across Thompson, Montville, Huntsburg, Middlefield and Parkman townships in Geauga County, and Nelson Township in Portage County when it turns southeasterly across Windham Township. Along this north and south escarpment there are various ledges and glens affording exposures of the Sharon conglomerate; but after the Thompson Ledge the one next best known is the Nelson. This is in Nelson, the northeastern township of Portage County, and as it is in the direct southerly continuation of the Geauga County escarpment, it will now be described. The Nelson Ledge is 5 miles northeast of Garrettsville near the Cascade Falls Hotel. Garrettsville is on the Cleveland division of the Erie Railroad and is also reached by the electric cars of the Chagrin Falls and Garrettsville division of the Eastern Ohio Traction Company.

The Sharon conglomerate is well shown at the Nelson Ledge where it is massive and the pebbles are thick. Some of them are as large as hen's eggs and in general they are decidedly larger than at the typical locality of the Sharon conglomerate to the west of Sharon, Pennsylvania. The matrix of the conglomerate is a coarse-grained sandstone or grit, in which the pebbles are imbedded, which on the face of the cliff and large blocks broken from it is of a brownish or rusty color. Plate LIX gives a view of a portion of the ledge showing differential weathering, pebbles and cross-bedding. In the amphitheater at the House Rock 39 feet of the conglomerate is shown. The contact of the Sharon conglomerate, and the Cuyahoga terrane is shown in the Old Hunter's cave under the cascade, where some 5 feet of argillaceous shale may be seen beneath the conglomerate. The upper part of the exposed Sharon conglomerate, as seen on the highway at the edge of the plateau just east of Nelson, is a thin-bedded, buff to brownish, coarse-grained, micaceous sandstone which is very much cross-bedded. There are occasional pebbles in these sandstone layers and this outcrop is near the highest ground on the highway. Two readings of the barometer with a difference in time of about 35 minutes between them gave a difference in elevation between the highest outcrops of the conglomerate seen on the highway east of Nelson and its base at Nelson Ledge of between 150 and 155 feet. Apparently in this region the Sharon conglomerate reaches a thickness of fully 150 feet. A fairly complete account of the conglomerate at this locality was published by John F. Carll in 1880.[1]

[1]Second Geol. Surv., Pa., I^3, p. 443.

Sharon conglomerate at Nelson Ledge showing quartz pebbles, cross-bedding and differential weathering.

CHAPTER IV

ASHTABULA AND TRUMBULL COUNTIES AND CRAWFORD COUNTY, PA.

These two Ohio counties lie between Lake, Geauga and Portage counties on the west and Pennsylvania on the east. The larger part of Ashtabula County is covered by the Chagrin formation while its southwestern and southeastern portions, together with the larger part of Trumbull County, are underlain by the various formations of the Waverly series. The southern and southeastern portions of Trumbull County show the Sharon conglomerate and some of the succeeding rocks of the Coal-measures.

The principal streams are the Grand and Mahoning rivers receiving numerous branches, of which Rock and Mill creeks are the largest entering Grand River and Mosquito Creek entering the Mahoning River. In the northeastern part of Ashtabula County, Conneaut and Ashtabula creeks are streams of considerable size flowing into Lake Erie while Pymatuning Creek rises in the southeastern part of Ashtabula County and flows across the northeastern part of Trumbull into Mercer County, Pennsylvania, where it enters the Shenango River. The southern half of Ashtabula and Trumbull counties is in the continuation of the plateau of northwestern Pennsylvania, except that a considerable part of Trumbull County has been decidedly lowered by stream erosion. Some of the streams have rocky banks for all or part of their courses, like the Grand River, which afford an opportunity to determine what geological formation borders them, while other streams have low alluvial banks as is the case with Mosquito Creek. Numerous smaller streams in descending from the higher ground of the western, southern and eastern portions of this area have cut through the soil, drift or alluvial deposits into the subjacent Paleozoic rocks and in several instances formed small glens. The Grand River rises in Nelson Township, Portage County and after reaching the northeastern corner of Farmington Township it flows nearly north until near the center of Austinburg Township, Ashtabula County, when it makes a turn nearly at right angles and flows westerly across the western half of Austinburg Township and Harpersfield Township into Madison Township of Lake County. That part of the two counties now under consideration which lies to the south and west of the Grand River will be considered first and most attention given to Trumbull, Hartsgrove, Windsor and Mesopotamia townships.

Trumbull Township. — To the north of Trumbull is Harpersfield Township which is underlain by the Chagrin formation and in the southern part of the township is the hamlet of Cork. At Cork the drift is reported as from 7 to 12 feet in thickness and farther east toward the Grand River it reaches a thickness of 100 feet. Shallow wells have been drilled in Cork and its vicinity which furnish natural gas from the Chagrin shales. The principal gas horizons were reached at depths of 135, 170 and 220 feet, while salt water was reached at 100 feet. From May to July, 1902, a well was drilled on the Oscar Dusenbury farm, one mile east of Cork, to a depth of 2,492 feet. It is reported that fresh water in abundance was obtained at a depth of 40 feet and a fairly good vein of shale gas at 300 feet, which of course was in the Chagrin formation. The statements differ as to the depth at which the Devonian limestone was reached as from about 1,700 feet to the one that the well "went at least 300 feet in the limestone". The reports of the residents of that vicinity agree that 80 feet of hard rock salt was penetrated in the well and samples were shown the writer. Salt water was struck at 2,200 feet, the rock salt was below it and the majority of answers gave the depth of the top as 2,400 feet. Mr. Gray, however, one of the most reliable men consulted, was not certain that the top of the salt was as deep as 2,400 feet. The Walle Bros. of Etna, Pa., who drilled the well, furnished the following record:

Shale occurs as in the wells about Jefferson, Ashtabula County, with two streaks of black shale near the bottom, also like the wells near Jefferson, to a depth of 1,740 feet when limestone was reached. Five hundred and ninety feet deeper at a total depth of 2,330 feet, the top of the rock salt was reached, which they gave as 90 feet thick. At its base was a streak of limestone below which was dark gray shale to the bottom of the well which they gave as 2,500 feet. The mouth of this well is 100 feet by the barometer higher than the bridge on the highway to the east over the Grand River in Austinburg Township.

It was also reported that wells in Saybrook Township, which is the one to the northeast of Harpersfield, obtain natural gas in considerable volume at a depth of 760 feet.

At Barnes Corners on the highway two miles east of Trumbull (known locally as Trumbull Center) are outcrops of coarse, greenish shales and sandstones. These rocks by the barometer are 60 feet higher than the bridge over Grand River on this highway to the east and they are in the Chagrin formation. They weather to a very rusty color; but it is not what a geologist calls red. Read in his description of the Erie shale (Chagrin formation) in Ashtabula County, stated that it "is composed almost entirely of soft, blue, aluminous shale, often weathering red on exposure, and finally decomposing into a stiff, yellow clay."[1] He also stated that "Hard layers, from one inch up to one foot

[1]Geol. Surv. Ohio, Vol. I, 1873, p. 486.

in thickness, are interstratified through these softer shale, but these bands are full of vertical seams, and are rarely of sufficient solidity to offer much resistance to denuding agencies."

By the roadside at the top of the ridge west of Barnes Corners and 55 feet higher, are outcrops of greenish-gray sandstone and shales which contain some fossils. There are rather poorly preserved specimens of *Spirifer disjunctus* Sowb., *Reticularia præmatura* (Hall) Schuchert, *Productella speciosa* Hall, *Athyris polita* Hall and some other species. The rocks as weathered are much iron-stained and seem to show that the water in which they were deposited was not very favorable for the existence of life. Apparently the sea to the northeast near Kelloggsville was purer water and better suited for the habitat of Mollusca. The top of the divide, to the east of Trumbull, is still 55 feet higher than the outcrop just described or 170 feet according to the barometer higher than the bridge on this highway over the Grand River.

The complete list of fossils from this locality, by the roadside to the west of Barnes Corners and about two miles east of Trumbull is as follows:

1. Reticularia præmatura (Hall) Schuchert .... (c)
   More specimens collected at this locality than of any other species. They agree in practically all details with specimens from Meadville, Pa., identified as this species by Dr. Kindle, which were studied at Cornell University. Later they were compared with types of this species in the New York State Museum from Meadville, Pa., with which they closely agree.
2. Spirifer disjunctus Sowb. .... (c)
3. Athyris polita Hall .... (r)
   A dorsal valve clearly shows faint radiating lines (striæ) as well as clear concentric ones as stated in Hall's description of this species.
4. Productella speciosa Hall .... (r)
   Compared with authentic specimens of this species at Cornell. The impressions of the pustules of the Ohio specimens agree with types of this species in the New York State Museum. The original specimens of this species were from the Chemung on Twenty-mile Creek, Chautauqua County, N. Y. Hall also reported it from Leon and New Albion in Cattaraugus County, and west of Olean in Allegheny County, N. Y. The range of the species is given by Professor Schuchert as Portage, Chemung and Kinderhook. It was reported as an abundant and characteristic species of the Ithaca formation by Dr. Kindle.[1]
5. Ambocœlia umbonata (Con.) var. gregaria Hall .... (r)
   One of these specimens is a dorsal valve and shows the rather narrow and fairly deep sinus of this variety. They were compared with a type specimen in the New York State Museum and are considered identical.

[1] Bull. Am. Paleontology, No. 6, 1896, p. 35.

6. Camarotœchia orbicularis Hall (?) ---------------------------- (rr)
7. Liopteria sp.-- (r)
8. (?) Sphenotus sp.-- (rr)

On Trumbull Creek about one-fourth mile south of Trumbull is a small gorge in which the upper part of the Chagrin formation and the Cleveland shale are shown. Blue argillaceous shales alternating with thin shaly sandstones are well shown in the creek within about 50 feet of the top of the Chagrin formation. These shales contain a considerable number of specimens of fossils of which *Spirifer disjunctus* Sowb. is the most abundant; but *Reticularia præmatura* (Hall) Schuchert *Camarotœchia orbicularis* Hall, *Athyris polita* Hall and a few other species occur. On the thin sandstones are numerous fucoidal markings together with some ripple-marks. Most of the fossils are in the sandy layers and the fauna suggests the zone on the highways between Grand River and Thompson. The complete fauna is as follows:

1. Spirifer disjunctus Sowb. ------------------------------------ (a)
2. Reticularia præmatura (Hall) Schuchert ----------------------- (r)
3. Camarotœchia orbicularis Hall -------------------------------- (rr)
4. Athyris polita Hall -- (rr)
   A specimen was compared with types of this species in the New York State Museum with which it closely agrees.
5. Athyris cf. cora Hall -- (rr)
6. Strophalosia muricata Hall (?) ------------------------------- (rr)
   These specimens are larger than the figures on pl. 22, Vol. IV, Pal. N. Y., and apparently somewhat wider in proportion to the length. This species was given by Hall as in the Chemung of Ellington, Chautauqua County, N. Y., and at Meadville, Pa., which remains the same in Schuchert's Synopsis of Fossil Brachiopoda.
7. Liorhynchus ohioense n. sp.----------------------------------- (r)
8. Productella sp.--- (rr)
9. Grammysia sp.--- (rr)
   An imperfectly preserved specimen, which perhaps may be compared with *G. communis* Hall from the Chemung of southeastern New York and Warren, Pa. The Ohio specimen, however, was compared with others at Cornell, identified and published as this species, by Professor Williams, from Cuba, N. Y. (Bull. U. S. Geol. Survey, No. 41, p. 64), and it does not agree in character of concentric folds, which are stronger than on the New York specimens. They are not as strong, however, as on specimens from near Olean, N. Y., identified as this species by Dr. Kindle.
10. Arenicolites cf. duplex Wms.
   The tubes of this specimen make a regular loop, which is much stronger and more regular than in the specimen figured by Professor Williams from the Portage shales of Wyoming County, N. Y. (Bull. 41, p. 46).
11. Fucoid markings.

Down the creek near the mill there is a rather high bank of the Chagrin formation. On the bank of the creek above the bridge is the upper part of the Chagrin formation capped by the Cleveland shale. More than 20 feet of the black Cleveland shale is shown, similar to the outcrops near Cleveland except there are some layers that are slightly impure, sandy and not so black as the normal Cleveland shale. Read in his description of the geology of Ashtabula County stated that "This black, bituminous shale is exposed in the ravines in Trumbull township, exhibiting there a maximum thickness of sixty-five feet; the upper thirty feet being a typical black shale, the lower thirty-five feet gradually assimilating to the character of the Erie [Chagrin] shale below."[1] In the Trumbull Creek glen there is scarcely any evidence of this transitional zone from the Chagrin formation to the 20 feet of black shale referred to the Cleveland. It is a steep bank and a good locality to study the contact of the Chagrin formation and the Cleveland shale.

In the southwestern part of Trumbull Township, near Footville, on the Lennon farm is an old quarry in the Berea grit which by the barometer is 105 feet lower than the Big Spring at South Thompson at the base of the Sharon conglomerate. The stone from this quarry was formerly known as the Trumbull Diamond grit and was used for whetstones. At one time there was a mill operated by Mr. Richardson who employed fifteen girls in labeling and other work connected with the preparation of the whetstones for market. The dirt banks of the quarry have mostly caved in so that there is not at present a very good exposure of the grit. Some of the layers show ripple-marks. This quarry was mentioned by Read in his Geology of Ashtabula County who stated that the Berea grit "enters Ashtabula county from the west, in Trumbull township, and near Footville has been quarried to a limited extent for whetstones, for which it is there very well adapted. Only a small part of the ledge has been exposed, and full explorations there would probably disclose good material for grindstones and for building purposes."[2]

On the creek bank about one-fourth mile north of Footville and just above a small iron bridge on the highway is a rock bank of about 10 feet. It is composed of bluish shales and thin-bedded bluish-gray sandstones which belong in the Bedford formation.

In the southern part of Trumbull Township, not far west of the north and south road from Hartsgrove to Trumbull and about 2 miles southwest of Trumbull a well was drilled in 1901 on the Green, formerly called the Johnson, farm. Judging from outcrops on Crooked Creek not far to the south it would appear that its mouth is near the horizon of the Berea grit. Mr. Daniel C. Rodgers, one of the drillers, has furnished the writer with the following record of this well: There was at

[1]Geol. Surv. Ohio, Vol. I, p. 486.
[2]Ibid., p. 484.

first 20 feet of drive pipe, then it passed through about 150 feet of clay and was cased at a depth of 150 feet shutting off all fresh water. Below the clay is about 500 feet of light colored shale and then about 700 feet of darker shale. At this horizon at a depth of about 1,370 feet was a show of what is called the Bradford sand, 30 feet thick, of dark color and tinted with red. Then 200 feet of shale, a little darker colored than that above, was passed through followed by what he called the Niagara shale, very black and 200 feet thick. At the base of this shale the sand, as Mr. Rodgers called it, was struck at a depth of 1,800 feet (but the sum of the thickness of the various zones above the sand as given by him amounts to 2,000 feet) which he described as of a darkish or very dark color and 150 feet thick. Below is a zone of about the same color, perhaps one-half of which is a regular flint with a thickness of 50 ± feet that would readily write on glass. Then it passed into what was called buttermilk sand from its resemblance to buttermilk; this had a disagreeable odor and was about 30 feet thick. Below this the well again entered the dark sand with very hard and soft streaks until a depth of 2,100 feet was reached (the sum, however, of the thickness of the various zones to the top of this deepest sand, as given by Mr. Rodgers, amounts to 2,230 feet). After casing off the fresh water the well was dry down to the bottom when very strong salt water with an acid nature was struck.

Mr. J. A. McFarland, who boarded the drillers, wrote that the well struck rock at a depth of 10 feet and from there until they reached a depth of 1,925 feet it passed through hard and soft shale. Rock salt was the last thing struck at a depth of 2,275 feet and there was a great flow of salt water which rose to within 400 feet of the top of the well.

Crooked Creek crosses the north and south highway from Hartsgrove to Trumbull nearly 2.9 miles north of the former village, 2.3 miles south of the latter and just south of the house of Mr. S. Potter. Just below the highway bridge in the creek are greenish to olive and bluish shales together with sandstones which form the upper portion of the Chagrin formation. The upper layers of the Chagrin at this locality are sandstones containing much iron pyrites and they resemble somewhat the top of the Berea. There is also an occasional ripple-marked layer. Some of the layers are rather fossiliferous and *Spirifer disjunctus* Sowb. is common and apparently runs to the top of the formation. Loose blocks in the creek apparently from this horizion contained specimens of *Spirifer disjunctus* Sowb. associated with *Strophalosia muricata* (Hall) Beecher, both of which were common. Specimens were shown Professor Williams who agreed in this identification. Later the Ohio specimens were compared with types of this species in the New York State Museum from Meadville, Pa., and from shape and general appearance they apparently clearly belong to this species.

The sandstone matrix has preserved scarcely any surface markings on the Crooked Creek specimens, except the rather heavy concentric wrinkles; but some of them agree almost precisely in size, general shape and outline with the type specimens, as for example fig. 34, pl. 22, Vol. IV, Pal. N. Y. The Meadville forms occur in weathered blocks in which are numerous specimens of *Spirifer disjunctus* Sowb., *Chonetes setiger* (Hall) de Koninck, *Camarotœchia contracta* Hall (?) and *Productella* sp. The types of this species came from the Chemung at Ellington, Chautauqua County, N. Y. and from Meadville, Pa., and this distribution remains the same in Schuchert's Synopsis of Fossil Brachiopoda. In addition a broken specimen of *Camarotœchia orbicularis* Hall (?) was collected at this locality.

On the bank at the bridge is shown about 18 feet of black, tough, thick-layered Cleveland shale. This is one of the best exposures of the Cleveland seen in this part of the State and there is apparently no evidence of the 35 feet of shale "gradually assimilating to the character of the Erie shale below" as reported by Read for this county.[1] The Cleveland shale is apparently sharply defined lithologically nearly if not quite to the top of the Chagrin formation at this locality.

Just below the highway there is evidence of the folding of the rocks. The sandstone in the bed of the creek above the bridge is dipping strongly to the north. A little farther up the stream the sandstone and shale dip sharply to the south showing that there is a small anticlinal fold.

Farther up the stream and about south of the well described above, are gray argillaceous shales of the Bedford formation. Thin-bedded sandstones are shown 15 feet higher than the gray, argillaceous shales and sandy shale occurs 10 feet higher than the thin-bedded sandstones. Thin-bedded but coarse-grained sandstone occurs 10 feet higher than the outcrop just mentioned and this is taken for the base of the Berea formation. The base of the formation is also indicated along the banks of this creek by numerous springs of excellent water. The mouth of the well to the north is by the barometer 10 feet higher than the outcrop of these coarse-grained sandstones on the creek, which is evidence that it began not far from the horizon of the basal part of the Berea sandstone.

To the south of Trumbull Township is that of Hartsgrove; but no particular time was devoted to a study of its geology. The Berea grit is exposed on the highway to the north of the village of Hartsgrove and also in Haskins Creek just south of the village.

Indian Creek Section and Quarry. — To the south of Hartsgrove is Windsor Township crossed by Indian and Phelps creeks which afford interesting sections of the formations, especially along the latter one. Indian Creek flows across the northern part of the township and in part of its course the rocks are fairly well shown. The following section

[1]Ibid., p. 486.

was studied along this creek commencing near the north and south road from Windsor to Hartsgrove.

Section on Indian Creek.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Berea sandstone.* Shown on creek bank just north of A. G. Atkins' house. Perhaps the top of the formation is not shown; but the layers of this upper exposed portion are mostly rather thin-bedded and much ripple-marked. Lower, there is massive sandstone, some of which is cross-bedded. The lower part of the Berea is massive, coarse-grained and somewhat friable. The lowest massive layer is about 6 feet thick; but above are thinner bedded layers	40	112
4.	*Bedford formation.* The contact of the Berea and Bedford formations is nicely shown on the southern bank of the creek, and is similar to that shown on Mill Creek in the southern part of the township. Immediately below the thick, basal layer of the Berea grit, is shown between 4 and 5 feet of bluish to gray, argillaceous and arenaceous, fine shales, with a few sandy layers or thin sandstones varying from one-half to one inch in thickness. At one locality the base of the Berea grit is shown on the creek bank directly above the top of the Cleveland shale, and the interval between these two formations represents the entire thickness of the Bedford, which by the barometer was 30 feet, and 32 feet by the hand-level	32	72
3.	*Cleveland shale.* Compact, black, massive shale in large rectangular blocks. At the place measured by the level, 18 feet of black shale was seen; but the Bedford was not shown. The measurements by the barometer along the creek indicated not more than 20 feet of the black shale	18+	40
2.	*Transitional layers.*		
	Grayish, soft, argillaceous shale — 1 ft. 10 in.	7 −	22
	Blackish shale, lower part of zone black and tough like Cleveland — 1 ft.		
	Soft, argillaceous, gray shale — 3 ft. 10 in.		
	Upper part of zone black and compact like Cleveland; lower part black but sandy — 3 in.		
	Total thickness of transitional layers — 6 ft. 11 in.		
1.	*Chagrin formation.* Olive, argillaceous and sandy shales, alternating with thin bands of sandstone. Perhaps some of the rock is bluish in color. At the first locality 3 feet is shown to the creek level; but on a lower bank 7 or 8 feet of shale and thin sandstone is exposed. The creek was followed down through 15 feet of the Chagrin formation; but probably there are lower outcrops of the formation on the stream. In loose blocks of the Chagrin along the creek specimens of *Spirifer disjunctus* Sowb., *Camarotœchia* and *Orthis* were seen.	15+	15

The above section shows that in Windsor Township there are shales which lithologically are transitional from the Chagrin formation to the Cleveland shale. That is, there are thin layers of black, tough shale like the Cleveland which alternate with grayish, soft, argillaceous shales having the lithologic appearance of the Chagrin. This transitional zone in the Indian Creek section has a thickness of nearly 7 feet and in a measure probably agrees with the shale that Read described in Trumbull Township as "gradually assimilating to the character of the Erie shale [Chagrin] below."[1] It is probable as these formations are followed toward Pennsylvania that shales with the lithologic character of the Chagrin gradually alternate with the black ones of the Cleveland; finally the gray ones predominate or entirely replace the black ones and in this way the Cleveland shale is eliminated.

At Stoneville, one and one-half miles up Indian Creek from the section just described, is the Stewart quarry in the Berea sandstone which is located on the bank of the creek one and one-half miles north of Windsor Mills and two miles northwest of Windsor. This quarry in September, 1902, showed the following section:

No.		Thickness. Feet.	Total thickness. Feet.
3.	A little shale cover in a few places but mostly till		
2.	The top course is composed of several thin layers, with a total thickness of 1 foot 2 inches	$1\frac{1}{6}$	21
1.	The remainder of the quarry is composed of light-gray to bluish-gray, coarse-grained, friable sandstone. The top course of this good stone is 6 feet thick, the next one below, 5 feet, then a 5-foot 4-inch course, with a 3-foot 6-inch course at the bottom of the quarry, making a total thickness of 19 feet 10 inches for this massive stone	$19\frac{5}{6}$	$19\frac{5}{6}$

The foreman stated that a diamond drilling showed 58 feet of good sandstone from the top down, then 3 feet of shale when sandstone was entered again. The dip from this quarry to Windsor Mills one and one-half miles to the south is according to the elevations obtained by the barometer 25 feet, or about 17 feet per mile to the south. The stone was then hauled six miles to Orwell for shipment by rail.

Phelps Creek Section. — Phelps Creek proper is formed in the eastern part of Huntsburg Township by the junction of the South Branch and North Branch. The former rises in the northern part of Middlefield Township and flows northeasterly, the latter in the southern part of Montville Township and flows southeasterly and after their junction Phelps Creek flows easterly across the eastern central part of Huntsburg Township, and the western central part of Windsor Township

[1]Ibid., p. 486.

to Windsor Mills, where it turns southeasterly and eventually enters Grand River.

The hamlet of Huntsburg is located at about the center of the township on high ground which descends steeply to the eastward and is underlain by the Sharon conglomerate which outcrops at various localities in the steep slope near Huntsburg. A ledge of the Sharon conglomerate occurs near the Huntsburg cheese factory, a short distance north of the hamlet and to the east of the highway leading north to Montville. The rock contains a considerable amount of white, quartz pebbles and in texture varies from a coarse-grained, brownish sandstone to a conglomerate. In a small run on the Buchanon farm to the south of the cheese factory, 15 feet or more of the conglomerate is shown and the base of the outcrop is probably near the base of the formation. The upper portion, which has been quarried to a small extent for bridge stone, is a coarse-grained, brownish sandstone, containing an occasional small white quartz pebble. The lower portion of the outcrop is much more pebbly than the upper and some layers contain a large number of quartz pebbles some of which vary from medium to fairly large size. Somewhat higher near the top of the small cascade is very marked cross-bedding.

Again in the field south of the highway, just east of Huntsburg and near the foot of the steep part of the hill, is a ledge of brownish sandstone composed of coarse, rounded grains of quartz sand which also contains some white quartz pebbles. About 5 feet is shown in the small quarry opening, which according to the barometer, is at about the same level as the middle of the ledge on the Buchanon farm. This rock is also shown to some extent in the road gutters farther down the hill.

On the bank of South Branch just below the bridge on the east and west road one mile south of the Huntsburg-Windsor Mills highway, are thin, even-bedded, blue, fine-grained sandstones alternating with shale. On the eastern bank a few rods below the bridge nearly 6 feet is shown composed mainly of blue sandstone but with some blue shale partings. The sandstone is fine-grained; but the grains are largely quartz sand and the color of the rock is blue. Some of the rock splits into thin, even layers like flags and other portions are thicker bedded reaching a thickness of a foot or more. A few poorly preserved fossils were noted in one of the shaly sandstone layers, one of which is a species of an *Orthis*. This zone has the general lithologic appearance of the *Sharpsville sandstones* and the comparatively level tract of country for some distance north and south in this region is probably held up by them. The stream was followed for some distance below this zone, although not to the highway a mile farther north, but only alluvial banks were seen. The barometer gave the difference in altitude between the top of this zone and that of the Berea sandstone at Windsor Mills, about $3\frac{1}{2}$ miles to the

northeast, as 110 feet with an interval of one and one-half hours between the readings and on the return as 90 feet with a difference in time of 55 minutes and a falling barometer. It is probable that the Orangeville formation has a greater thickness than 110 feet in this section since in Mesopotamia Township, only about 5½ miles farther south, there is good evidence for considering it 140 feet thick

The South Branch, commencing some rods south of the Huntsburg-Windsor Mills road, was followed continuously until its junction with the North Branch and then Phelps Creek to Windsor Mills. The following section was obtained, but the measurements are largely barometric and of course subject to some error.

Section on South Branch and Phelps Creek.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Cuyahoga terrane.* On the South Branch, some rods south of the Huntsburg-Windsor Mills highway, are blackish, in part argillaceous shales, alternating with thin sandstones	5	55+
4.	Thin, blue sandstone in shale, 1 to 2 inches thick, exposed in the creek bed a few rods north of highway bridge. The upper surface shows markings like those of fucoid stems. This zone is 160 feet lower than the lowest outcrops of the Sharon conglomerate on the highway east of Huntsburg, according to one barometric reading, and 185 feet according to another. On a direct trip from this zone to the top of the Berea formation at Windsor Mills, the barometer, with a difference of 50 minutes between the readings, made the difference in altitude 55 feet instead of 50 feet as given in this section	$\frac{1}{6}$	$50\frac{1}{6}$
3.	Partly covered zone; but on bank of Phelps Creek is a shale bank, the lower portion of which is composed of fissile, black shale, with some very thin layers of harder rock. These harder layers are somewhat concretionary, apparently calcareous, and the outcrop very much resembles the shale and concretionary zone above the *Spirophyton* sandstone, on Rocky River, to the southwest of Cleveland	10	50
2.	High bank on southern side of Phelps Creek, more than a mile above Windsor Mills, and also above lane leading north from the school house, past the house of Eldred Alderman, to the creek. The base of this bank is 25 feet lower by the barometer than the creek, at the bank noted above. From 35 to 40 feet above the creek level is a sandstone layer 3± inches thick, and above this sandstone are rather numerous thin, sandstone layers, alternating with shales. Below this 3±-inch sandstone, the bank is composed of rather tough, black shale, some of which is rather gritty and the other soft and argillaceous. There are, however, a few layers of		

No.		Thickness. Feet.	Total thickness. Feet.
	sandstone from a fraction of an inch to perhaps 2 inches in thickness in this part of the bank. About 15 feet higher than the base of this bank, as shown on the northern side of the creek, a few rods above the swing bridge on the lane, is a thin sandstone layer, apparently from 2 to 4 inches thick, which is the lowest one seen	10	40
1.	This lower zone is composed entirely of fine, black shale, as it appears on the weathered banks of the creek. Below the swing bridge, on the northern side of the creek, is a long bank of black shale, while visible toward the top of the cliff is a thin, sandstone zone, which is the one noted on the bank above the swing bridge. This bank, below the thin sandstone, has the typical appearance of the Brecksville shale, dark in color, with smooth face and no projecting layers. This carries the section down to a sandstone shown in the bed of the creek some distance above Windsor Mills, which is regarded as the top of the Berea formation. The barometer was rising when this section was measured, so that between the base of the lowest cliff of black shale, and the top of the Berea sandstone, no difference in altitude was obtained. Consequently, it is probable that this zone of black shale is somewhat thicker than the 30 feet that was obtained by the barometer. The difference in altitude between the lowest outcrops of the Sharon conglomerate, just east of Huntsburg, and the top of the Berea formation, in Windsor Mills, is according to the barometer about 215 feet	30+	30

This section as found on Phelps Creek and South Branch apparently shows that in what corresponds to the Brecksville shale of the Orangeville formation of this region there are thin layers of sandstone. If not, then the Orangeville formation is very thin, since it is not much more than 30 feet from the top of the Berea up to the lowest thin sandstone. It is, however, believed that the Orangeville formation extends up South Branch well toward the upper sandstone which has already been described, the top of which occurs barometrically from 90 to 110 feet higher than the top of the Berea. If this be true then in the eastern part of the State there are thin bluish sandstone layers in the upper part of the Orangeville shale; while the even-bedded blue Sharpsville sandstone occurs considerably higher than the lowest of these thin and somewhat irregular blue sandstones. These lower sandstones, however, are not especially different from some of the lower ones in the Royalton formation as shown on Rocky River to the south of Berea. The occurrence of thin sandstones in that part of the Orangeville formation corresponding to the Brecksville shale has already been described

in certain sections, as for example in the stream above Stebbins Gulch and will be likewise noted in Walnut Creek at Cortland.

Phelps Creek flows through Windsor Mills and has cut a gorge of some depth, the lower part of which below the mill is known as Warner Hollow. The hollow is the deepest part of the gorge with steep banks from 40 to 60 feet or more in height formed of ledges of Berea grit and altogether making a picturesque ravine. To the north of the iron bridge in the hamlet and on the eastern bank of the creek is the following section:

Section in Northern Part of Windsor Mills.

No.		Thickness. Feet.	Total thickness. Feet.
6.	Soil bank.		
5.	Weathered surface of layers which are greatly iron-stained; some fossils were found.		
4.	*Sunbury shale.* Thin, black, fissile shale, which as weathered is somewhat brownish, and some of it is grayish, with the lithologic appearance of the Sunbury. Specimens of *Lingula melie* Hall and *Orbiculoidea herzeri* Hall and Clarke are common	$5\frac{1}{2}$	17
3.	*Berea sandstone.* This stratum is believed to represent the top of the Berea formation, which is roughened from the decomposition of iron pyrites as is generally the condition of the upper surface of the Berea. It is a massive stratum of sandstone, which in places splits into somewhat irregular layers, composed of quartz grains and containing much iron pyrites. The exposed edges of the stratum and blocks broken from it are very hard. Lithologically it resembles the top zone of the Berea formation in Stebbins Gulch rather than the Chardon sandstone as shown farther up that stream	$1\frac{7}{12}$	$11\frac{1}{2}$
2.	Zone of bluish shale, not black, which is partly argillaceous and partly arenaceous, with thin lenses of sandstone. A considerable proportion of the bluish shale is very arenaceous, showing, when broken, that it is composed to a large extent of fine quartz sand. There are also very frequent sandstone lenses, part of which are composed of the coarse, white quartz sand of the Berea, although part of them are rather fine-grained, and some are ripple-marked. The lithologic characters of this zone are much more similar to those of shale zones seen in the Berea formation, as for example, on Phelps Creek, in the southeastern part of LeRoy Township, than any outcrop of Sunbury shale that the writer has ever seen. The general appearance of the bank, however, when seen at a distance suggests strikingly that of the Sunbury shale with the Aurora sandstone above. This zone is thought to be similar to the one near the top of the Berea formation described in Stebbins Gulch, to the northwest of Chardon; except that		

No.		Thickness. Feet.	Total thickness. Feet.
	there the subjacent sandstone zone is $4\frac{1}{2}$ feet thick, while the shale zone has almost the same thickness, viz., 8 feet	$7\frac{2}{3}$	$9\frac{11}{12}$
1.	Massive sandstone layers, not very regular, with numerous ripple-marks to creek level	$2\frac{1}{4}$	$2\frac{1}{4}$

A view of this section is given in Plate LXI, A, where the man is standing on top of zone No. 1; the shale zone No. 2 is opposite him while above is clearly shown the sandstone of zone No. 3 which is regarded as forming the top of the Berea formation.

A little farther up the creek on the same side a small gully shows 18 feet of shale above the sandstone of No. 3 in the above section. No fossils were found in it. Some of the shale has a rather bluish to grayish tint; but much of it is very black, especially in the lower half of the exposure. The laminæ are apparently a little thicker in the upper half; there is also an occasional sandy layer and perhaps it is not so prevailingly black in color. There is apparently no decided lithologic break in this bank of shale, although if it were steeper and well washed, perhaps a greater difference in lithology might be shown. The sandstone shows a strong dip down the stream in the direction of S. about 60° E.

To the west of the creek is the excavation, now filled with water from 6 to perhaps 20 feet in depth, where the Pittsburg company opened an extensive quarry, which was in the massive stone of the formation, the top of which is shown in No. 1 of the above section, and the company planned for extensive operations. A branch railroad $8\frac{1}{2}$ miles in length was built to Burton; but the two leading men died and it was abandoned.

On the southwestern side of the quarry is a conspicuous shale bank which shows the shale of No. 2 in the above section and the sandstone of No. 3 above which is the black Sunbury shale, probably 15 feet of which is shown.

The upper part of the massive sandstone and the superjacent shale zone and sandstone at the top of the Berea formation are well shown on the northwestern bank of the creek opposite the lower end of the fall below the dam and opposite Windsor Mill.

The deepest part of the gorge is below the mill and fall and the highway bridge on the north and south road. This part of the gorge is known as Warner Hollow which affords fair exposures of the Berea sandstone and also shows the subjacent Bedford and Cleveland formations.

General Section of the Gorge in Warner Hollow.

No.		Thickness. Feet.	Total thickness. Feet.
6.	Top of *Berea formation*. The upper surface of this sandstone is greatly pitted as weathered, with the appearance of having contained many nodules of iron pyrite. It is somewhat irregularly bedded, of grayish to buff color, fairly friable, and from 1 foot 6 inches to 1 foot 7 inches thick. Shown by roadside, south of bridge, below Windsor Mill ----	$1\frac{1}{2}$	129+
5.	Shaly zone, shown in the road gutter, at the southern end of the bridge. Bluish-gray, argillaceous shale with thin, interbedded sandstones, which weather rather brownish in spots ------------------------	$8\frac{1}{6}$	$127\frac{2}{3}$
4.	Main portion of the Berea grit, which is even-bedded, the layers varying in thickness from one-half to 4 feet. Some 25 feet is shown on the bank at the highway bridge, with heavy layers in the middle. The thick layers, some of which measure 4 feet, are grayish to buff in color, the buff showing numerous brown spots, and are friable, with the characteristic feel of the Berea grit. In the creek, a little below the bridge, are thin-bedded layers, which are conspicuously ripple-marked. Some of them are rather bluish, others brownish in color, and the bluish ones are not as friable as the brownish. The bed of the creek, about one-fourth mile below the bridge, is on the Berea sandstone, and according to the barometer, the top of the massive sandstone by the bridge is 55 feet higher than this exposure in the bed of the stream. The lower portion of the formation contains some undulating layers as shown on the bank, and there are two somewhat conspicuous layers of bluish shale shown above the lowest undulating layer. The upper part of the bank, however, is composed of rather massive sandstone. The contact of the Berea and Bedford formations is shown near the base of a cascade in a small run entering the creek from the west, and this section will be fully described later. The barometer with an interval of 35 minutes between the readings, gave a difference of 60 feet between the top of the formation on the highway near the bridge, and its base in the cascade mentioned above-----------------------	55+	$119\frac{1}{2}$
3.	*Bedford formation*. A foot and 7 inches of shale at the top of the formation is shown in the cascade. The upper part of the Bedford as here exposed is crumpled; but this irregularity does not appear at all in the superjacent Berea sandstone. A few rods farther down the stream is a conspicuous bank, the lower part of which is composed of the Bedford formation, and the upper two-thirds of the Berea.		

No.		Thickness. Feet.	Total thickness. Feet.

The Bedford consists of shales, alternating with sandstones, which vary in thickness from 1 to 4 or 5 inches. The Bedford and Berea are dipping into the bank to the west rather strongly, so that apparently the uplift or folding occurred after the deposition of the Berea sands. The upper surface of the Bedford is markedly uneven at the line of contact, and the upper foot or two has been more or less disturbed. This is clearly shown in some of the upper thin, sandstone layers, which have been broken, and the pieces pushed out of position. Where there is a depression in the shale, the lower massive stratum of the Berea is thicker than where it rests on the ridge of the Bedford. In other words the base of the Berea corresponds with the undulating surface of the Bedford formation, with a corresponding variation in the thickness of the lowest stratum of the Berea. This structure recalls the contact of these two formations in Smith's Run, to the southwest of Lithopolis, in central Ohio, some account of which the writer has already published.[1] Two or three rods farther down the stream the Cleveland shale is shown, where it is dipping at a high angle, 20° or more, S. 30° W., and near the center of the creek the dip is apparently still greater. At this locality, by level, up the bank from the top of the Cleveland to the base of the Berea, gives only about 28 feet for the thickness of the Bedford formation. Mr. Morse also leveled this interval at this locality and got 28½ feet for the thickness of the Bedford. No correction was made for the dip, which is steep from the fold toward the bank, and this would increase the thickness somewhat; still the horizontal distance is small, and the bank steep, so that the amount to be added is probably not great. It appears that the thickness of the Bedford at this locality can not be over 35 feet, and perhaps not more than 30. This shows that erosion has cut down into the Bedford deeper at this locality than at most others that have been described.

Farther down the creek, where the path leads from the top of the eastern bank down to the springs and pool at the side of the travertine rocks, the Cleveland shale, Bedford formation and superjacent Berea sandstone are shown. The Bedford shale is rather light-gray in color, with some mottled red and gray at the base, but lighter colored at the top. The shale is much disintegrated and partly covered with soil. The con-

[1]Am. Geologist, Vol. XXXIV, 1904, p. 345. See particularly Fig.6 on pl. XIX. Also Jour. Geol., Vol. XX, 1912, pp. 597-599 and see fig. 3 on p. 599.

No.		Thickness. Feet.	Total thickness. Feet.
	tact of the Bedford and Berea formations on this bank is an irregular line; but there is no crumpling shown at the top of the Bedford. As near as could be determined from leveling, the Bedford formation is 47 feet thick as limited on this bank. Mr. Morse got 44½ feet for this interval	47	64½
2.	*Cleveland shale.* Tough, bituminous shale, splitting into even, slaty layers, which are characteristic of this shale, and sometimes weathering to a rusty color. Perhaps 10 feet of it is shown at the outcrop 2 or 3 rods below the Bedford-Berea cliff, and at the lowest bank there is 15 feet exposed	17½+	17½+
1.	*Chagrin formation.* On the southern bank of the creek, a little farther down than the travertine blocks, the top of the Chagrin formation is shown, with the black Cleveland shale resting on top of it. At the top of the Chagrin formation is a sandstone zone with a thickness of 1 foot 3 inches, which splits into several layers. The sandstone is bluish to grayish in color, the upper layer containing numerous grains of iron pyrites, so that the rock is greatly iron-stained on the surface, and worm trails or "fucoidal markings" also occur. A little lower are ripple-marks and sun-cracks. These upper sandstones are fossiliferous, containing *Spirifer disjunctus* Sowb., *Productella, Camarotœchia* and Pelecypods. A loose block of sandstone from Phelps Creek, in Warner Hollow, contained numerous specimens of a Pelecypod, which was listed as *Spenotus* cf. *clavulus* Hall. This sandstone at the top of the Chagrin is similar to the one at the top of this formation on Mill Creek, which is the next stream to the south. Below the sandstone are blue, arenaceous shales, and thin sandstones for a foot to water level. Below the outcrop just described, the banks are not steep, and the Chagrin rocks are mostly covered by the blocks brought down the stream.		

Three heavy layers of the Berea sandstone are shown in the old quarry, just above the bridge on the north and south road, with a total thickness of 19½ feet. The thickness of the layers is as follows: top one 5½ feet, middle 10 feet and bottom 4 feet. According to Mr. Wilson, the miller, a drilling commencing on top of this quarry went down 50 feet before it reached shale (Bedford ?). At the four corners in Windsor Mills, a few rods northeast of this bridge, is apparently the decomposed black Sunbury shale, weathered to a rusty brown color.

On the banks of the stream in Warner Hollow some distance below the bridge the following zones were measured in the lower part of the

Berea sandstone; but it does not, however, extend as low as the base of the formation:

Section of Lower Part of Berea in Warner Hollow.

No.		Thickness. Feet.	Total thickness. Feet.
5.	Shaly, sandstone zone to arenaceous shale zone, with very even beds, the layers from 1 inch to less than ½ inch in thickness. Zone from 3 feet 4 inches to 3 feet 8 inches thick, showing ripple-marks	3⅓	22½
4.	Layers of thin-bedded sandstone from 1 to 2 inches in thickness. Much ripple-marked; a layer of clay is often found over the ripple-marks, with pittings like those made by rain drops	1 5/12	19⅙
3.	Conspicuously cross-bedded zone. Lower part shown farther down the stream, with undulating layers, not so strongly cross-bedded, and with ripple-marks. Coarse-grained, quartz sandstone, with brown spots. Sun-cracks shown at the base	7½±	17¾
2.	Bluish shale with lenticular lenses of coarse-grained, bluish sandstone. Shale in places is argillaceous	1¾	10¼
1.	Massive, coarse-grained sandstone, some of it with cross-bedding	8½	8½

A run enters Phelps Creek from the west in Warner Hollow and only a few rods from its mouth is a cascade of some height over the Berea sandstone with the upper part of the Bedford formation shown at its base. A section was leveled up this run by Mr. Morse and across the highway to the bank on the opposite side in which the Sunbury shale occurs.

Section up Western Run in Warner Hollow.

No.		Thickness. Feet.	Total thickness. Feet.
15.	*Sunbury black shale.* The lower part is shown as a weathered bank above the highway cutting, which is just south of the run	--	--
14.	*Berea formation.* Coarse-grained, rusty sandstone, 3½ inches thick. This sandstone is also shown in the gutter on the opposite side of the road to the north of the run, with black, weathered shale above and arenaceous shale below. This zone evidently corresponds to the one described by the roadside just south of the bridge over Phelps Creek, about one-half mile farther north, where it has a thickness of 1½ feet	¼+	64⅓
13.	Arenaceous and argillaceous shale zone, the arenaceous predominating, in cutting by highway. Four and one-half feet of this shale is shown here, and then on the opposite side of the road is a covered interval of 2 feet 7 inches down to the top of a thick-bedded sandstone. By the roadside, at the bridge mentioned above, is a		

No.		Thickness. Feet.	Total thickness. Feet.
	shaly zone 8 feet 2 inches thick, which probably represents the shale zone and covered interval just described in this section	$4\frac{1}{2}$	$64\frac{1}{12}$
12.	Covered interval, probably shale, similar to the zone above	$2\frac{7}{12}$	$59\frac{7}{12}$
11.	Thick-bedded layer	$1\frac{1}{3}$	57
10.	Thin-bedded sandstone, ripple-marked	$1\frac{3}{4}$	$55\frac{2}{3}$
9.	Shale zone	$\frac{2}{3}$	$53\frac{11}{12}$
8.	More or less massive sandstone, extending nearly to the top of the bank	$18\frac{2}{3}$	$53\frac{1}{4}$
7.	Arenaceous shales to shaly sandstone	1	$34\frac{7}{12}$
6.	Thin-bedded, ripple-marked sandstone	$5\frac{1}{3}$	$33\frac{7}{12}$
5.	Layer splitting into several thin ones	$\frac{2}{3}$	$28\frac{1}{4}$
4.	Shaly sandstone zone	$1\frac{1}{6}$	$27\frac{7}{12}$
3.	Fairly massive, coarse-grained sandstone, which is somewhat contorted and cross-bedded	17	$26\frac{5}{}$
2.	Thin-bedded sandstone, extending to the base of the formation. The lowest $1\frac{1}{2}$ feet typical, massive, coarse-grained, quartz sandstone	$7\frac{5}{6}$	$9\frac{5}{12}$
1.	*Bedford formation.* Bluish shales shown in the cascade directly beneath the massive Berea sandstone, which in the upper part are somewhat crumpled. On the bank of the run below the cascade several feet of the upper Bedford, mostly shales, are exposed below which is a covered interval to the level of Phelps Creek; but these two lower zones were not measured	$1\frac{7}{12}$	$1\frac{7}{12}$

In the above section it will be seen that the Berea formation has a thickness of almost 63 feet, and as this was obtained by careful leveling, it may be accepted for the general thickness of this formation in Warner Hollow. The barometer with an interval of only 10 minutes between the readings gave 65 feet for the thickness of the Berea in the above section. This thickness of 63 feet for the Berea formation near Windsor Mills is greater than that given by Read for this locality. His statement in the "Geology of Ashtabula County" is that "the best exposures [of this formation] are at Windsor Mills where the stream has cut a channel thirty to forty feet deep through the rock, and where it has been quarried for many years for local use."[1]

Just a little below the mouth of the run above described there is an uplift on Phelps Creek, which has brought up the base of the Bedford formation and the Cleveland shale. The contact of the two formations is shown in this anticlinal fold near the southern (western) edge of the creek, and in a few inches at the base of the Bedford there are fossils as *Syringothyris*, *Lingula*, *Microdon*, etc. In the black shale, apparently at the top of the Cleveland, are specimens of both a large and

[1]Geol. Surv. Ohio, Vol. I, p. 484.

small form of *Lingula*, and the majority of the larger Lingulas lie crosswise of the bedding of the shale.

A short distance below this uplift is the cliff on the southern (western) bank of Phelps Creek, where the very interesting contact of the Bedford and Berea formations occurs, which has been partly described in the general section of Warner Hollow. The section of this cliff is as follows:

Section of Contact Cliff of Bedford and Berea Formations.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Berea sandstone.* It forms the upper part of the cliff, and the lower layer, which is massive, is in contact with the Bedford. Thickness not measured; but estimated as 40 feet or more	40	54⅓
3.	*Bedford formation.* Zone of shales and thin sandstones of varying thickness, due to removal of more or less of its upper portion. At the upper end of the cliff only the lower 7 inches of the zone is preserved, while at the lower end this zone is about 4 feet thick	3±	14⅓
2.	Fine-grained sandstone, varying in thickness from 3½ to 4 inches	⅓	11⅓
1.	Blue shales, both argillaceous and arenaceous, with layers of thin sandstone, some of which are 6 inches thick. Below these shales talus slope to level of old channel of creek; but it was not measured	11	11

The contact between the Bedford and Berea formations is excellently shown in this cliff as well as the conspicuous variation in the thickness of the upper portion of the Bedford formation due to erosion. The 4-inch sandstone of zone No. 2 in the above section may be readily followed from the upper (northern) end of the cliff for some distance across its face. At the upper end, near the small gully, there is an interval of 7 inches of blue shale from the base of the Berea coarse sandstone (zone No. 4) down to the top of the 4-inch sandstone (zone No. 2). Plate LX of the upper end of this cliff shows the contact of the Bedford and Berea formations, which is indicated by the hammer, while Mr. Morse's left hand rests on the 4-inch sandstone of zone No. 2. At a distance of 6 feet along the face of the cliff from its upper end this interval (zone No. 3) has increased in thickness to 1 foot 10 inches. At a distance of 14 feet from the first measurement this interval is 3 feet or more in thickness, showing an increase *above* the lower 7 inches noted at the upper end of the cliff of 2½ feet in a horizontal distance of 14 feet, while farther along the cliff toward the lower end it becomes greater, but this was not reached for exact measurement. In the shales above the 4-inch sandstone (zone No. 2), as followed across the cliff toward the lower end, additional thin sandstones appear, which have been cut

Disconformity between Bedford and Berea formations in Warner Hollow, below Windsor Mills.

away by erosion at the upper end of the cliff. Near the lower end there is a sandstone in the upper part of the Bedford, which is fully 6 inches thick, and at this end it must be fully 4 feet from the horizon of the 4-inch sandstone up to the base of the Berea. Here and there on the cliff there is more or less crumpling in the upper layers of the Bedford and at one place apparently a sandstone dike filled with coarse sand like that of the Berea. Probably this was an open joint in the upper part of the Bedford filled with the coarse sand of the Berea when that formation was deposited.

The upper surface of the lower massive layer of the Berea is about horizontal, while the under surface is uneven, corresponding to the inequalities of the upper surface of the Bedford. This makes the thickness of the lower layer of the Berea uneven, corresponding in a way with that of the Berea as shown on Smith's Run, southwest of Lithopolis in central Ohio, and which the writer has described in a former paper.[1] This cliff appears to show unquestionably that there is a *disconformity* between the Bedford and Berea formations.

The uplift has raised the Berea, pitching it into the bank so that it appears to be shown that the folding occurred after the deposition of the Berea. The axis of the fold apparently extends in an easterly and westerly direction.

The Cleveland black shale is exposed in the creek opposite the cliff where near the center of the stream it is dipping very strongly to the south. More of the shale is shown on the southern bank of the stream a few yards below the cliff. As already stated, at this locality the writer obtained 28 feet for the thickness of the Bedford and Mr. Morse 28½ feet. This measurement does not include any correction for the dip, so that it is quite probable that there is some 30 feet and perhaps as much as 35 feet of the formation left at this locality or not much more than its lower half.

Some distance down the creek from the contact cliff is a bank on its northern side, the lower part of which is composed of Bedford shales and thin sandstones, some of the layers of sandstone from 2 to 4 or 5 inches thick, with massive Berea sandstone above. The contact of the two formations is not clearly shown and it adds nothing to our information concerning the disconformity. The Bedford shales and sandstones are dipping into the bank away from the creek in a direction more or less opposite to that of the layers in the contact cliff on the opposite bank farther up stream. This appears to show that the axis of this fold has been cut out to a considerable extent by this stream which it follows. Somewhat farther down the creek the Cleveland shale occurs in its bed with the axis crossing it, and toward the lower end of the outcrop there is not a heavy dip.

[1]Am. Geologist, Vol. XXXIV, 1905, pl. XIX, fig. 6 and see p. 345 under the description of the Berea sandstone. Also see paper on "The disconformity between the Bedford and Berea formations in central Ohio," Jour. Geol., Vol. XX, 1912, pp. 597–599.

On the northern bank of the creek above the travertine blocks $17\frac{1}{2}$ feet of Cleveland shale is exposed. There is fully this thickness, for the base is not shown, although the base of the outcrop is probably not much above the Chagrin; and the contact with the Bedford is also covered, although it is probably not more than a foot or so higher.

Below the travertine rocks on the southern bank of the stream is an outcrop showing the contact of the Chagrin formation and the Cleveland shale as has been described in the general section. At this locality the rocks are dipping N. 20° E., so that the axis of the anticline is to the south of the creek.

The northern bank of the stream just above the travertine blocks was leveled by Mr. Morse, where the following section was obtained:

Section of Bank of Warner Hollow at Travertine Rocks.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Berea sandstone.* Top of exposure as shown near brink of cliff above the springs and contact of the two formations. Mainly coarse-grained quartz sandstone, which is rather massive. At base 6 to 7 inches of very thin-bedded, more or less lenticular, layers of coarse sandstone, alternating with shaly material. Thickness $46\frac{1}{2}$ feet by level, and 45 feet by barometer	$46\frac{1}{2}$	$108\frac{1}{2}$
2.	*Bedford formation.* Blue, argillaceous and arenaceous shales, with layers of rather thin, blue, compact, fine-grained sandstone. For this interval Mr. Morse obtained a thickness of $44\frac{1}{2}$ feet and the writer 47 feet, but it is thought that in the latter measurement the base of the formation was taken a little lower, since at that time only 14 feet of Cleveland shale was shown	$44\frac{1}{2}$	62
1.	*Cleveland shale.* Black, bituminous shale to creek level at the pool. From the creek level at this point to the base of the Berea in the cliff above, was 62 feet as leveled, and 60 feet by the barometer	$17\frac{1}{2}+$	$17\frac{1}{2}+$

In the cliff above the travertine rocks the contact of the Bedford and Berea formations is clearly shown. This section is not more than one-eighth of a mile down the stream from the "contact cliff" on its opposite bank, where it does not appear that the thickness of the Bedford formation is over 35 feet, while on this bank it is $44\frac{1}{2}$ feet or more.

A thin sandstone layer in the upper part of the Bedford formation near the eastern end of the exposed contact dips about 6°, and at the western end a higher thin sandstone is dipping $6\frac{1}{2}$° N. 110° W. The 3- to 4-inch Bedford sandstone on the western side of the cliff upon which the dip was measured, is faulted at places with both normal and reversed faults. At one place in the reversed fault there is a displacement (*throw*) of 1 foot 9 inches. On the 3- to 4-inch sandstone layer, where it is carried up by the reversed fault, the dip is about 8° N. 110°

W. Near the eastern end of this sandstone the thickness of the interval from its top to the lowest thin-bedded Berea sandstone is 2 feet 5 inches, and at the western end of the bank with a horizontal distance of 5½ feet to 6 feet, the interval is 3 feet 10 inches, or 1 foot 5 inches more than at the other end of the outcrop.

At the base of the Berea in this cliff are 6 to 7 inches of thin-bedded coarse-grained quartz sandstones alternating with shaly material before reaching the conspicuous coarse-grained layers. The lower portion of the formation, however, is composed of layers more or less thin-bedded, showing numerous ripple-marks. The lower layers of the Berea lie about horizontal, the variation being too slight to read on a clinometer.

This cliff seems to show conclusively that at the contact of the Bedford and Berea formations the Bedford had been elevated and planed off before the Berea was deposited on its beveled edges so that there is a *disconformity* between the two formations. There is some irregularity in the surface of the Bedford so that the base of the Berea is not strictly a smooth and straight line; but it conforms to the uneven surface of the Berea upon which it lies more or less horizontally.

This glen is a most interesting one for studying the contact between the Bedford and Berea formations. It shows in the lower section apparently a disturbance preceding the deposition of the Berea sandstone, when the Bedford shales were tilted, while their upper surface is uneven, apparently due to erosion, and shows a disconformable contact. At the upper, or contact cliff, it appeared to the writer that the Berea as well as the Bedford was pitching into the bank; but there is a conspicuously uneven surface of the Bedford showing a marked *disconformity* between the formations. There appears to be an anticlinal fold in the Bedford opposite the upper cliff which the creek has cut through, and at this locality the upper part of the formation, as shown about one-eighth of a mile farther down the stream, is wanting. At the upper cliff there is apparently not much more than 30 feet of the Bedford formation left, while the lower bank shows 44½ feet or more.

From the several sections described along Phelps Creek and then up to the Sharon conglomerate as exposed at Huntsburg, the following section has been compiled, which is arranged in diagrammatic form. The thickness of the Orangeville formation and of the covered interval from the Sharpsville sandstone to the Sharon conglomerate were obtained by the barometer and are not as accurate as might be desired, because conditions were somewhat unfavorable.

General Section of Formations from Warner Hollow to Huntsburg.

Elevation	Thickness	Beds	Formation
379 '			
	15 '+	Sharon conglomerate	
364 '			
	125 '±	Covered	
239 '			
	6 '	Sharpsville sandstone	
233 '		?	
	74 '±	Blackish shales, with some thin sandstones	Orangeville formation
159 '		Sandstone layer 2 to 4 inches	
	30 '+	Clear black shale	
129 '+			
	1½ '	Upper sandstone	Berea formation. Thickness 65 feet
	8 1/6	Shale zone	
	55 '	Main mass of Berea sandstone	
64½ '			
	47 '	Bedford formation	
17½ '			
		Cleveland shale	
	17½ '+		
0 '		Chagrin formation	

Mill Creek and Well Sections. — Mill Creek flows across the southwestern part of Windsor Township and crosses the north and south road about 1.7 miles south of Windsor Mills. The Berea sandstone is shown on the Charles Howard farm just east of the highway, and the creek was followed for about three-fourths of a mile until the east and west or Cassa Springs road was reached on the Wm. Woodruff farm. The banks of Mill Creek between the two roads for a considerable part of the distance are formed of outcrops of the Paleozoic rocks. Below the Cassa Springs road the valley broadens; but there are banks from 25 to 35 feet in height which are composed of blue boulder clay and sand with the clay at the bottom. The following section was prepared from outcrops in the stream and on its banks:

Section on Mill Creek.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Sunbury shale.* It is shown on the highway just north of Mill Creek and the former house of Mr. Emory Jones, but that of B. L. King in the summer of 1909.		
4.	*Berea sandstone.* The top of the formation is shown in the creek just east of the highway and house of Mr. King. As a rule, the Berea is rather thin-bedded along		

No.		Thickness. Feet.	Total thickness. Feet.
	this stream where it forms its bed and banks for some distance. Much of it is ripple-marked and there is more or less cross-bedding. There is a thin shale zone toward its top; but not such a conspicuous one as at Windsor Mills. The lower part of the Berea is a thicker bedded sandstone, while the basal 5 feet or so is a massive one. Oil oozes out of the sandstone at various places along the creek, and formerly oil was collected from shallow wells in this valley, some of them from 50 to 80 feet in depth. The contact of the Berea and Bedford formations is shown on the southern bank of the creek, some rods down the stream from the fall, where was formerly a mill. One reading of the barometer gave 90 feet for the thickness of the Berea and another 70 feet; but its thickness in the well on the Emory E. Jones (now King) farm is given as 80 feet, which is probably the more accurate	80	135
3.	*Bedford formation.* On the bank where the contact of the Berea and Bedford formations is shown, there are 2 feet or more of Bedford blue shale and thin sandstones below the Berea. In the upper part of the formation, some 15 feet of grayish and bluish, argillaceous shale is shown on the creek bank. Farther down the stream is a bank that shows the lower part of the formation, where there is more than 12 feet of olive, argillaceous shale, below which is a 6-inch sandstone, and then an 8-inch layer of sandy shale marks the bottom of the formation	35	55
2.	*Cleveland shale.* On the bank just described, 14 feet of black, compact, bituminous shale underlies the sandy shales at the base of the Bedford formation. The layers of this shale are rather thick, and perhaps there is 2 feet more of it before reaching the Chagrin sandstone	16±	20
1.	*Chagrin formation.* Bluish, micaceous sandstone, with numerous "fucoidal markings." A little farther down the creek, perhaps 8 feet of the upper part of this formation is shown	4	4

The above section shows that the thickness of both the Cleveland shale and the Bedford formation decreases as they are followed across the eastern part of the State. Messrs. Homer and Emory E. Jones reported that on the bank of the creek to the east of the Emory Jones farm on the farm of Charles Howard is an oil spring, and that a number of shallow wells have been drilled in the Berea grit on this farm, which yielded lubricating oil. These wells varied in depth from 35 to 54 feet. There are certain rather soft layers in the upper and middle portions of the Berea at this locality which contain oil. It comes to the surface along the banks and in the joints in the bed of

Mill Creek, and dried oil is frequently shown on the edges of these layers. The intervening layers do not contain oil; neither is it found in the lower portion of the formation. The majority of the wells were drilled along the creek, and one of them yielded 2,000 gallons of oil, which was sold for from 35 to 40 cents per gallon, thereby bringing the owner between $700 and $800. At one point years ago a drift was carried into the bank, about 20 feet above the base of the formation, in the hope of obtaining oil.

In the fall of 1902 a well was drilled on the Emory E. Jones farm (now owned by B. L. King) to the depth of 2,467 feet, which is located near the farm buildings. The Sunbury shale is shown on the highway at a lower level than the mouth of this well, so that apparently the first black shale struck in it belongs to the Sunbury. This well was drilled by Mr. J. C. Mastick, who furnished a partial record of it. His account is supplemented somewhat by information furnished by Mr. Emory E. Jones, together with the writer's examination of samples of drillings from a depth of 1,380, 1,750, 2,000 and 2,165 feet.

Section of Well on the Emory E. Jones (now King) Farm One and One-half Miles South of Windsor Mills.

0′		Mouth of well
	20′	Soil, till and boulder clay
20′	5′	Black shale, Sunbury
25′	76′	Rusty layer at top of Berea Berea grit
101′	1′	Layer of soft shale
102′	1278′	Alternating light and dark shale Sample at 1380′ composed mainly of argillaceous shale. Most of the chips have a white streak; but some have a slightly brownish one
1380′	1′	Thin layer of sandstone
1381′	25′	Dark colored shale
1406′	89′	Light colored shale
1495′	250′	Reddish-brown shale
1745′	262′	Sample at 1750′ composed of argillaceous shale, with white streak Lighter colored shale
2007′	21′	"Sandstone" of Mr. Mastick
2028′	97′	Sample at 2000′ composed of black, compact shale, which is somewhat calcareous with brownish streak
2125′	342′	Sample at 2165′ composed of light-gray, fine chips, which effervesce strongly in cold HCl. This sample is apparently from the Devonian limestone Limestone of Mr. Mastick
2467′		Bottom of well

Mr. Jones reported that the limestone was struck at 2,000 feet; but this appears to be an error, since the sample from that depth received from him consists of black compact shale. Samples, however, were shown the writer at the well when it was reported as 2,066 feet deep, which consisted of dark gray calcareous chips that had all the lithologic appearance of the Devonian limestone. This seems to show that the sample from 2,165 feet was below the top of the Devonian limestone. Still if the top of the Devonian limestone is not reached

until at a depth of 2,165 feet, then the interval from the base of the Berea grit to the top of the Devonian limestone, or the thickness of the Bedford and Ohio shales, is but 2,064 feet; while in the Hadsell well near Cortland, some 16 miles to the southeast, as reported by Dr. Bownocker, the same interval is 2,396 feet[1] or 332 feet greater. Mr. Jones reported that from 2,200 to about 2,400 feet there was flint in the limestone, which looked like arrow heads, but from 2,400 feet there was a change and the rock was not quite so hard and was of a darker color. Mr. Mastick gave the following information concerning the occurrence of oil and gas in the well. At a depth of 92 feet oil and gas in the Berea sandstone; at 1,380 and 1,495 oil in the Ohio shale; at 2,007 oil and gas; at 2,125 oil; at 2,160 oil and gas; at 2,250 gas, and at 2,430 oil. No salt water was struck. Mr. Lamsom, of Middlefield, who owns the farm adjoining that of Emory E. Jones, reported that near the bottom of the well 8 feet of oil sand was passed through. Mr. Mastick reported oil at a depth of 2,430 feet, and if the top of the Devonian limestone was reached at about 2,066 feet, then the interval from the top of the Devonian limestone to the oil-bearing sandstone is about 364 feet. This is about 36 feet less than the thickness for the same interval on the Hermitage farm near Little Mountain; but is identical with the thickness of this interval in the Jewett farm well, south of Cleveland, while in the Euclid well, east of Cleveland, it is but 372 feet.

Two streams south of the Jones farm cut into the Brecksville shale, which is fairly well exposed in their banks both above and below the north and south road.

A well drilled for water at the creamery in Windsor, which is one and one-half miles east of Windsor Mills, is 230 feet deep. There was some flow of gas which was followed by salt water. It was reported that gas would flow for a time, when it would spout water to a height of perhaps 18 or 20 feet, and then after a time gas would flow again. The lower and greater part of this well is in the Chagrin formation.

Traction Cut and Andrews Creek Section. — Mesopotamia Township adjoins Windsor Township on the south, and in its western part, in descending from the higher land to near the level of the Grand River Valley, are the rather extensive cuts on the Cleveland and Sharon Traction road and the exposures in Andrews Creek. The Andrews Creek gorge is some 4 miles southwest of Mill Creek at the Jones farm. On the eastern escarpment of the plateau and on the high ground to the north of the creek are the traction cuts, the highest of which begins near the western line of Mesopotamia Township, opposite the W. J. Griffin farm, nearly 4 miles east of Middlefield and 2+ miles west of Mesopotamia. At this writing the company has not completed the road; but these cuts for the proposed road while new

[1]Geol. Surv. Ohio, Vol. IX, Bull. No. 8, 1906, p. 39.

afforded an excellent opportunity for studying a considerable part of the Cuyahoga terrane. The cuts are in the Sharpsville sandstone and shales of the Pennsylvania classification, which immediately succeed the Orangeville formation, and when fresh afforded one of the best localities for studying the Sharpsville that the writer has seen in eastern Ohio.

Section of Cleveland and Sharon Traction Road Cuts and Andrews Creek.

No.		Thickness. Feet.	Total thickness. Feet.
9.	Soil.		
8.	*Upper Sharpsville sandstone.* Thin-bedded, flaggy, fine-grained sandstone, the layers of which vary from 1 to 3 inches in the lower part. The color as weathered is mainly buff, but on fresh exposure sometimes bluish, although when dry, generally light gray. This zone is shown in the small run and upper cut, where 10 feet is exposed, according to both the hand-level and barometer	10	323
7.	*Sharpsville shale.* Upper part of this member contains many more layers of thin sandstone than occur in the lower, and the change is gradual from the upper sandstone. Lower portion composed almost entirely of blue, arenaceous shale, with thin layers of sandstone. The fossils are probably most abundant in the calcareous layers of these shales. The thickness of this member is 25 feet by both the hand-level and barometer.	25	313
6.	*Lower Sharpsville sandstone.* Mainlv light gray, fine-grained, micaceous sandstones, separated by layers of blue, arenaceous shales; sandstone layers from 3 to 8 inches in thickness, with occasionally a thick one from 1½ to perhaps 2 feet. An occasional layer of sandstone has a decidedly mamillated appearance, covering large blocks of fairly massive sandstone, which is probably a form of concretionary structure. The base of this sandstone is shown at the eastern end, and near the bottom of the deep traction cut. Its thickness is 35 feet according to one reading of the barometer and 29 feet as determined by the hand-level, which is the more reliable	29	288
5.	*Orangeville formation.* The upper 10 feet of this formation is shown in the lowest part of the deep traction cut, and consists of soft, bluish, rather argillaceous shale, with an occasional thin, sandy and harder layer. The shales for some distance below the Sharpsville sandstones are fairly well exposed and show no sandstone layers with a greater thickness than an inch or so, and consequently it is apparent that the rocks of this portion of the section are principally shales. Below, for some distance, it is mainly a covered slope; but 70 feet lower than the base of the cut, in a small		

No.		Thickness. Feet.	Total thickness. Feet.
	run, which enters Andrews Creek from the north, is shown blue, thin, argillaceous shale. Twenty feet lower, in Andrews Creek, is black and rather tough shale, which represents the *Sunbury* member of this formation. It weathers to a rusty color, and near the middle of the exposures on the creek, specimens of *Lingula melie* Hall are abundant in laminæ of the shale, while *Orbiculoidea herzeri* Hall and Clarke occurs infrequently. The larger specimens of *L. melie* Hall at this locality are about 11 mm. long and 7.5 mm. wide. This is in close agreement with the type specimen of this species in the American Museum, fig. 3, pl. 1, Vol. IV, Pal. N. Y., which has a length of 11 mm. and a width of 7.2 mm. From the top of the highest exposure of this black shale to the top of the Berea grit, in the bed of the creek, is 10 feet by the barometer, and the black shale is shown on its bank, not more than 2 feet higher, a couple of rods or so farther up the stream. From the base of the Sharpsville sandstone to the top of the Berea grit is 140 feet by the barometer, which represents the entire thickness of the Orangeville formation	140	25
4.	*Berea formation.* The top of the sandstone is shown in the bed of Andrews Creek, just above the Bundysburg highway, where its upper surface is full of iron pyrites, and rough from its disintegration, as is generally the condition of the upper surface of this formation. This zone, by level, is 16 feet thick, and 20 feet according to the barometer. It is the writer's recollection that in this zone is the Charles Clark quarry, which is only a few rods below the road, where building, flag and bridge stone is quarried. Part of the layers are rather thin, from 3 to 4 inches, especially near the surface, and many of them show abundant ripple-marks. On the eastern side of the quarry, about 14 feet of rock is shown. According to Mr. A. R. Harshman, this upper sandstone dips to the northeast, and years ago he quarried stones in this zone that contained drops of greenish oil	16	119
3.	Shale zone, composed of soft, argillaceous, gray shale, which splits into small pieces. A few sandy layers near the top and bottom of this zone, which has a thickness of 6 feet 9 inches	7—	103—
2.	Lower sandstone zone begins in the bed of the creek, several rods above the A. R. Harshman sawmill, and extends for several rods below it. It is a massive, fairly coarse-grained sandstone, which is apparently more massive than the upper zone, and was formerly quarried by the Ohio Freestone Company. Mr. Harshman states that this quarry is 14 feet deeper than the surface of the water now standing in it. By hand-level, from the lowest exposures of this sandstone to its top is 21 feet. A well, however, drilled at this mill, began about		

No.		Thickness. Feet.	Total thickness. Feet.
	3 or 4 feet below the top of this zone and passed through 33 feet of this sandstone, according to Mr. Harshman. Its mouth is 18 feet above the lowest exposures noted in the creek, which indicates that this sandstone zone extends 15 feet below the base of the present exposures, making its total thickness 36 feet. It will be noticed that this lower 15 feet obtained from the well record is in c ose agreement with Mr. Harshman's statement that the sandstone in the old quarry was worked to a depth of 14 feet below the base of the present exposure.	36	96
1.	*Bedford formation.* The well, according to Mr. Harshman, was drilled to a depth of 93 feet, or 60 feet below the base of the above described sandstone. Immediately below it for some depth was shale, then a sandstone with another shale below it, and the well finally stopped in a very hard sandstone	60	60

This well was drilled in 1863, and for some years it yielded some gas. The sandstone extends for about 20 rods below the sawmill and then the creek valley broadens and, according to Mr. Harshman, the country becomes flat with only alluvial deposits exposed. In the above section it is thought that the base of zone No. 2 marks the base of the Berea formation, which gives it a thickness of about 59 feet. The shale of zone No. 3 in the Berea formation of the above section was evidently noted by Read, since he stated that "The Berea in Mesopotamia is separated into two parts by about two feet of shale."[1]

Sections Near Warren.—The city of Warren is located on the northern bank of the Mahoning River in the townships of Warren and Howland. The country in the vicinity of Warren is fairly level, so that no long sections may be obtained; but there are occasional rocky banks on the Mahoning above Warren and exposures at certain other localities in the vicinity of that city which are of interest.

Leavittsburg is 3 miles west of Warren, and between these two towns the Mahoning River makes a big bend to the north. Just below the highway bridge at Leavittsburg on the bank of the Mahoning River 6 feet of bluish, argillaceous shale with alternating layers of micaceous sandstone is shown. Some of the sandstone layers reach a thickness of 3 inches and they contain much iron pyrites. There are also concretionary, calcareous, rusty, lenticular stones which form more or less continuous layers. The bluish shales do not contain many fossils; but a *Chonetes* was noted. The top of some of the sandstone layers is very rough as though covered with fucoidal markings, and some of them are like stems which on weathering out leave hollows. There is a rather strong dip in the direction of 40° S. of E., or 140° E of N.

[1]Geol. Surv. Ohio, Vol. I, p. 508.

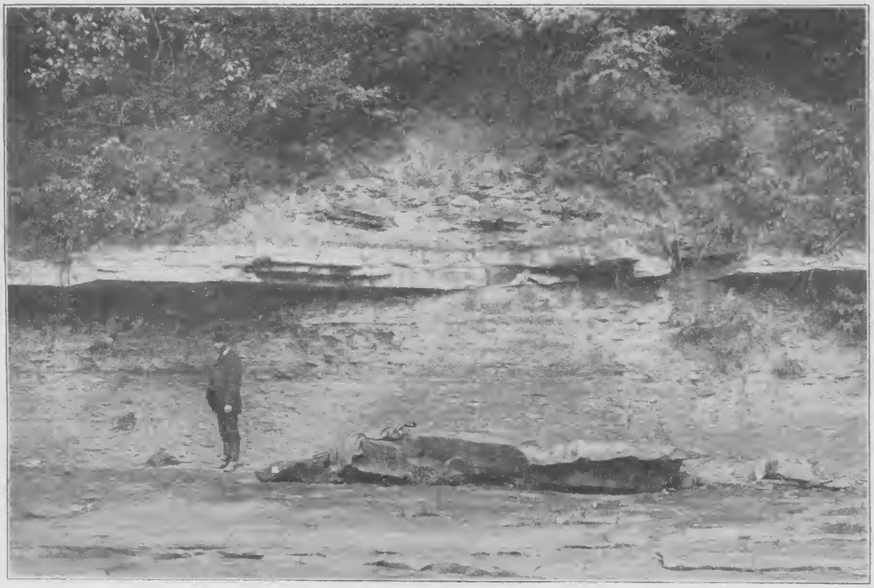
On the western bank of the Mahoning River $2\frac{1}{2}$ miles or more above the Warren Court House Park, and above the little hamlet of Edgewater, is a rocky bank showing the following section: At the base a blackish, fissile shale, about 8 feet in thickness; at the top of this shale is a thin sandstone, above which is another zone of shale, capped by a thin sandstone. Some of these shales are fairly gritty and rather grayish or bluish-gray in color. The Berea sandstone is not shown at the water level, as is the case in the outcrop a mile farther down the river, which will next be described, and a hasty examination seemed to indicate that this shale is in the Brecksville overlying the Sunbury; but the examination was too hurried to be positive regarding this correlation.

On the farm of Warren Brobst and the western bank of the Mahoning River, $1\frac{1}{2}$ miles above the Court House Park in Warren, an anticlinal fold brings up the Berea sandstone. At the base about 4 feet of Berea sandstone, which is mainly thin-bedded, is shown above low water. The sandstone is of buff color, the layers more or less bent and some of them have ripple-marks. On top of this sandstone is a black shale which probably represents the Sunbury, in the lower part of which are immense numbers of *Lingula melie* Hall, together with specimens of a larger *Lingula*, which are not nearly so abundant as the former.

A still thicker and better section of this portion of these formations is shown on the eastern bank of the Mahoning River below the house of Alfred Fitch, rather more than one-fourth mile above the Warren water works.

Section on Mahoning River, One-fourth Mile above Warren Water Works.

No.		Thickness. Feet.	Total thickness. Feet.
5.	Soil and clay.		
4.	Sandy layers to sandstone.		
3.	*Aurora sandstone* (?). Bluish to light gray, compact, fine-grained sandstone and those overlying probably belong in this zone	$\frac{3}{4}$	$16\frac{3}{4}$
2.	*Sunbury shale* (?). The top of this member is rather impure and sandy, perhaps in places 1 foot of sandy shale at top. Black to brownish-black shale, some of it very black and compact, with the lithologic characters of the Sunbury. The lower part contains immense numbers of *Lingula melie* Hall and a smaller number of specimens of another species of *Lingula*	14	16
1.	*Berea sandstone.* Fairly fine-grained, very uneven-bedded sandstone which contains a large quantity of iron pyrites, so that on weathering there is a rough upper surface. A little below, in thinner layers, are numerous ripple-marks. This sandstone appears above water		



A.—Bank on Phelps Creek at Windsor Mills showing upper part of Berea formation. See page 628.

B.—Bank of Mahoning River above Warren showing Sunbury shale (?) and overlying sandstone. See page 647.

No.		Thickness. Feet.	Total thickness. Feet.
	on the arch of a small anticlinal fold. At the time it was studied, the upper 2 feet of the formation was exposed, while on the river bank, both above and below the outcrop of sandstone, the Sunbury black shale (?) runs down to water level	2±	2

This bank is shown in Plate LXI, B, where the Aurora sandstone (?) of zone No. 3 appears as a conspicuous projecting ledge, beneath which is the comparatively smooth bank of Sunbury shale (?).

On the same bank of the river, about one-fourth mile below the section just described and a short distance above the Warren water works and the Erie Railroad bridge, is the following section, the rocks of which are apparently stratigraphically above most of those of the former section:

Section above Warren Water Works.

No.		Thickness. Feet.	Total thickness. Feet.
7.	Soil and till.		
6.	Apparently shale.		
5.	Bluish-gray sandstone	$\frac{1}{4}$	16
4.	Soft, bluish-gray, very argillaceous shale	$2\frac{3}{4}$	$15\frac{3}{4}$
3.	Compact layer of bluish-gray, fine-grained sandstone	$\frac{3}{4}$±	13
2.	Blackish shales at top, containing specimens of *Lingula*, the smaller and more numerous ones of which closely resemble *L. melie* Hall. The shales are mainly bluish-black in color; but there are thin, bituminous laminæ, especially in the upper part, and alternating with the shales are thin layers of bluish sandstone, which are thicker near the base of the cliff. There are also some layers that are slightly concretionary, and weather to a very rusty color. Specimens of *Lingula* are numerous in the blackish shales near the top, and some were also collected in those near the base of the section.	11	$12\frac{1}{3}$
1.	At the upper end of the exposure, where the rise brings up the lower rocks, about $1\frac{1}{3}$ feet of coarse, arenaceous shales to bluish-gray sandstones are shown, below the shales of No. 2. This stratum is apparently the upper portion of the Aurora sandstone (?) which is shown in the section farther up the river, on top of the Sunbury shale (?); while the overlying shales belong in the Brecksville	$1\frac{1}{3}$	$1\frac{1}{3}$

The prominent sandstone layer at the southern end of the cliff is 9 feet 10 inches above water level, and 420 feet farther north, at the northern end, 12 feet 4 inches above the water, giving a dip of 2 feet 6 inches for that distance to the southeast or at the rate of $31\frac{1}{3}$

feet per mile. This shale and sandstone are apparently shown on the opposite bank of the river.

Read in his geological report of Trumbull County under the description of the Cuyahoga shale wrote as follows: "In the bed of the Mahoning, west of Warren, the abundance of *Lingulæ* and the lithological peculiarities indicate that the stream at this point cuts nearly through these shales, and that the Berea grit is to be found at no great depth below. Here was obtained a very perfect and well preserved spine of *Ctenocanthus* (*C. formosa*), figured and described by Prof. Newberry."[1] From the above statement it appears probable that Read only saw the lower bank of shale above Warren and did not see those where the anticlinal fold brings up the Berea; or else the water was higher at the time of his examination, so that the sandstone was covered.

Dr. Newberry was acquainted, to some extent at least, with the outcrop of these shales near Warren, since under his description of the Cuyahoga shale published in 1874 he stated that "in the northern and eastern portions of the State the base of the Cuyahoga shale is formed by a fine, thinly laminated, dark gray, sometimes black, clay shale, full of *Lingulæ* and *Discinæ*. This bed is exposed at a great number of localities, of which Berea and Chagrin Falls, in Cuyahoga, and Warren in Trumbull county, may be cited as examples."[2]

Dr. Orton reported that "from this latter horizon [Buena Vista] come in great part the natural flaggings of the state. In Trumbull county of northeastern Ohio, the Berea shale grows very thin and thus the upper quarry courses come down close upon the Berea grit."[3] Later he wrote as follows: "The Berea shale seems to be reduced in this region [Warren] to a thickness of about 8 or 10 feet. It is, however, well characterized by the Discina and Lingula which belong to the horizon. In many places it is almost entirely composed of these shells."[4] It is evident that in this instance the Berea shale described by Dr. Orton is equivalent to the zone that probably represents the Sunbury, although generally he included in it the grayish to blackish shale overlying the Aurora sandstone.

Prof. H. P. Cushing has published a section of the rocks through Warren in which he gave the thickness of the Berea grit as 10 feet, and the Berea shale of Dr. Orton as 55 feet.[5] Professor Cushing stated that "north of Warren another sandstone appears directly under the black shale [Sunbury (?)] and is the equivalent of the lowest sandstone on the state line [Pennsylvania-Ohio] of the Corry sandstone of Prof.

[1]Geol. Surv. Ohio, Vol. I, p. 504.
[2]Ibid., Vol. II, p. 88.
[3]Proc. Am. Assoc. Adv. Sci., Vol. XXX, 1882, pp. 173, 174.
[4]Geol. Surv. Ohio, Vol. VI, 1888, p. 321.
[5]Proc. Am. Assoc. Adv. Sci., Vol. XXXVI, 1888, p, 214.

White in Pa., of the Berea of northern Ohio. That it is the Berea is shown:

1. By the hard, black, sandy, sulphurous layer, two inches thick, which separates it from the black shale above. This stratum occurs nearly everywhere above the Berea in Ohio and I did not find it above either of the other sandstones at this point.

2. By the nearly black shale [Sunbury (?)] with a black shale fauna, which directly overlies it, and whose stratigraphical relations (as exhibited in the sections) show that it could not possibly be the Cleveland shale.

3. By the series of blue shales and flags, Bedford, underlying it.

4. By the fact that neither of the other sandstones here can represent the Berea. The upper is too near the Conglomerate and is underlaid by 100 feet of strata with Cuyahoga shale fossils. The middle one is the equivalent of the sandstone at Warren, and apparently nearly runs out just west of that point, being shaly and having only about a thickness of 6 feet in the Mahoning River, west of Warren."[1]

On the bank of a run to the northwest of Warren, where it is crossed by the extension of Mahoning Avenue opposite the house of Mr. E. E. Hughes, is an outcrop. The lower part consists of about 5 feet of dark gray to blackish shale, which is partly rather sandy and tough, and in the blackest portions specimens of *Lingula melie* Hall are common. These specimens have about the typical proportions of this species, and one that was measured is 8.5 mm. in length and 5.5 mm. in width. A few specimens are similar to fig. 9, pl. 20, pt. 2, Vol. VII, Geol. Surv. Ohio, which Professor Herrick called *L. cuyahoga* Hall. This figure is 12.9 mm. long and 7 mm. wide and smaller than the type specimen of this species in the American Museum, which is 15 mm. long and 10 mm. wide; but an examination of the type specimens of *L. melie* and *L. cuyahoga* led the writer to believe that Herrick's figure perhaps represents *L. melie* rather than the latter species. Some specimens of *Orbiculoidea herzeri* Hall and Clarke (?) also occur. The shale is capped by about 1 foot of light colored, fine-grained sandstone. There is a rather heavy dip down stream to the southwest, and the shales are about as black as those in the lower part of the Brecksville or even some of the Sunbury. This outcrop is probably not more than 20 or 30 feet higher than the level of the Mahoning River near by, and it is probably the upper portion of the Sunbury shale capped by the Aurora sandstone (?).

Some years ago a well was drilled on the Park Square in Warren, a record of which follows:

[1]Ibid., p. 215.

Section of the Park Well at Warren.

Depth	Thickness	
0′		Mouth of well
	126′	Soil and shale for 126 to 128 feet
126′		Top of first grit Sand down to 160 or 170 feet
	44′ ±	At base, white sand like that under the oil at West Mecca
170′		Shale at bottom of well

It appears probable that the 44 ± feet of sand in the well represents the Berea grit, although it is given at a greater depth than the writer expected. It indicates a very strong dip to the southeast from the outcrops already described on the Mahoning River above Warren.

Rather more than $2\frac{1}{2}$ miles northeast of Warren are the Kinsman and Austin quarries, which formerly were worked rather extensively and furnished flagging stone of large size.

Section of the Kinsman Quarry.

No.		Thickness. Feet.	Total thickness. Feet.
3.	Upper sandstone stratum, which is bluish-gray in color, and splits in part into fairly thin, flaggy layers; but they are not very even	$2\frac{1}{4}$	$6\frac{1}{4}$
2.	Blue, somewhat arenaceous shale, which on the surface weathers to a rusty color, varying in thickness from 1 foot 11 inches to 2 feet 4 inches	$2\frac{1}{3}$	4
1.	Lower sandstone, which is similar in color and bedding to the upper one; but in places it becomes one layer, 1 foot 8 inches in thickness. The sandstone is bluish-gray, compact, fine-grained and hard. One slab had ripple-marks. This sandstone has no resemblance to the Berea and evidently belongs in the Sharpsville sandstone of the Cuyahoga terrane. The bottom of this zone and sandstone is not shown	$1\frac{2}{3}$	$1\frac{2}{3}$

Some of the dirt and clay overlying the sandstone is of reddish color, probably due to the weathering of iron in some of the rock. The Austin quarry across the road from the Kinsman has been worked more extensively; but neither has been worked much since 1899. The Austin shows the same two sandstones as the Kinsman; but the cover is deeper and on top of the upper one is about 4 feet of bluish, arenaceous shale, similar to that between the two sandstones.

To the west of these quarries and about 20 feet higher is the old line of the Erie Railroad. This is also on the divide and the ground descends to the west, so that it is probable that in the vicinity of War-

ren the Sharpsville sandstone will not be found much farther to the westward, because it has been removed by erosion.

Professor Cushing in his Warren section gave the thickness of these Warren sandstones as 25 feet[1] and stated that "this stone is *beyond doubt* the equivalent of the middle sandstone near the state line [Pennsylvania-Ohio], that is as certainly the equivalent of the Sharpsville sandstone of Prof. White in Crawford County, Pa."[2]

Dr. Orton thought that the Berea shale became very thin in Trumbull County, so that the flagging stone near Warren, which he regarded as the equivalent of the Buena Vista stone of southern Ohio and the Sharpsville sandstone of Pennsylvania, came "down close upon the Berea grit."[3] He also stated that Dr. White's "Sharpsville sandstone is our Buena Vista stone, and his Corry sandstone appears to be none other than the Berea grit."[4] In the Buena Vista section in southern Ohio there is a zone of fire clay and blue and drab shale with a thickness of about 5½ feet between the Sunbury shale and Buena Vista sandstone. If the Buena Vista sandstone represents the Sharpsville of eastern Ohio, then this shale zone must represent the Brecksville shale which has thinned from 105 feet at its typical locality on Chippewa Creek in the Cuyahoga Valley to the 5⅓ feet in the Ohio Valley. The writer has recognized a sandstone perhaps corresponding to the Buena Vista in central Ohio with a similar shale between it and the Sunbury; but he is not confident that it is the Sharpsville sandstone of northern and eastern Ohio. On the contrary he inclines to the opinion that the Buena Vista sandstone thins out before reaching northern Ohio, and that the Sharpsville sandstone occurs at a higher stratigraphic horizon. In fact, the Aurora sandstone occurs nearer the stratigraphic position of the Buena Vista, with this exception, that there is no gray or drab shale between it and the top of the Sunbury shale.

A series of old quarries and pits may be followed from the Austin and Kinsman quarries to the southeastward to the Ewalt quarry, worked by George Ewalt. The barometer made the top of the Ewalt quarry about 58 feet lower than the base of the Austin; but this rapid descent is probably due to the anticlinal fold which apparently runs from Mecca to the Mahoning River west of Warren. The layers of stone in the Ewalt and Lampson quarries, the latter one-fourth mile southeast of the former, are not so thick as in the Kinsman and Austin quarries; but the color and coarseness of grain of the good sandstone is very similar in all of them.

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[1]Proc. Am. Assoc. Adv. Sci., Vol. XXXVI, p. 214.
[2]Ibid., p. 215.
[3]Geol. Surv. Ohio, Vol. VI, 1888, p. 38, and Vol. VII, 1893, p. 31.
[4]Ibid., Vol., VII, p. 33.

Section of the Ewalt Quarry.

No.		Thickness. Feet.	Total thickness. Feet.
9.	Soil	2±	17¾
8.	Shale and some shaly sandstone	4	15¾
7.	Sandstone layer, 4- to 6-inch course of quarrymen	½	11¾
6.	Shale	¾	11¼
5.	Sandstone, splitting into layers, the "hard stone" of the quarrymen from 8 to 9 inches thick	¾	10½
4.	Blue shale, from 18 to 30 inches in thickness; but generally about 18 inches	1½	9¾
3.	Gray, flaggy sandstone	3	8¼
2.	Shale from 2 to 3 inches thick	¼	5¼
1.	Blue, flaggy sandstone, to that used for "rough rock", the layers from 2 to 5 inches in thickness	5	5

Mr. Ewalt stated that they find occasional layers with ripple-marks. He considers that his quarry contains the same series of layers as was formerly worked in the Austin to the north of Warren, which furnished the excellent flagging. Mr. Ewalt said that there were several layers in the Austin quarry which could be depended on to run evenly, and that those were formerly worked extensively; but have not been in some years. He thinks that this sandstone zone runs out to the west of the Austin-Kinsman quarries and he knows of none west of those. Mr. Ewalt stated that the dip in his quarry, the Lampson and all in this region, is to the southwest.

It is true that the fairly even-bedded, flaggy layers in these quarries resemble considerably the even layers of the Buena Vista sandstone as shown in the quarries to the west of Portsmouth. This similarity in bedding is probably one of the reasons which led Dr. Orton to consider these sandstones identical with the Buena Vista.

The Lampson quarry is about one-fourth mile southeast of the Ewalt, about 3 miles east of Warren, just south of the highway and only a short distance west of Mosquito Creek. The top of the bottom sandstone in the Lampson is, according to the barometer, 5 feet lower than the bottom of the Ewalt quarry, and from 75 to 80 feet lower than the ridge to the west. The sandstones when wet are of blue color, but when dried are really a light drab to light gray tint and of pleasing color. Some of the layers of sandstone are even-bedded and valuable for flagging, while others are not so good and cut obliquely across. The shales alternating with the sandstones are bluish, but some as weathered are rusty and contain iron-stone concretions. Some of the layers of flagstone are bent or curved at the edge of the quarry, and some of them in the bottom of the quarry vary from 8 to 18 inches in thickness. Mr. Lampson stated that the 4-inch layers are best for his work, and the stone makes flagging, caps, sills, cistern covers and rough rock. He further said that the flaggy layers

thicken as they are followed to the westward, and he thinks that the stone of his quarry is not in the same zone as that of the Austin-Kinsman quarries to the north of Warren. In this quarry there is a dip of 2 feet in a distance of 100 feet to the west and of 1 foot in 100 feet to the south. The rock is somewhat fossiliferous, the largest number of specimens occurring in the lowest sandstone, although what Mr. Lampson called a "fossil screw" was found in the second sandstone from the top, probably a specimen of a *Dictyophyton*. The thickness of the zones of the following section of this quarry was furnished by Mr. J. B. Lampson, the quarryman:

Section of the Lampson Quarry.

No.		Thickness. Feet.	Total thickness. Feet.
10.	Soil and drift	5	24½
9.	Shale	5	19½
8.	Top sandstone, from 4 to 6 inches thick	½	14½
7.	Shale	1	14
6.	Sandstone stratum in several layers, containing "fossil screw"	1	13
5.	Shale and shaly sandstone	3	12
4.	Zone of flagging and wall stone in several layers	3	9
3.	Shale	½	6
2.	Flagging in several layers. Most of the fossils come from between the layers and near the base of this zone	2½	5½
1.	Shale or soapstone of the quarryman	3	3

Zone No. 2 of the Lampson quarry apparently corresponds with zone No. 1 of the Ewalt, and from these zones up there is the same number of similar lithologic ones in both quarries, varying somewhat in thickness. The total thickness for this portion of the two quarries, however, is about the same, viz., 15¾ feet in the Ewalt and 16½ in the Lampson, and it probably represents the Sharpsville sandstone of western Pennsylvania.

On the eastern side of Mosquito Creek, on the Warren M. Brown farm and only a short distance from the Lampson quarry, a well was drilled to the depth of 3,071 feet. The barometer indicates that its mouth is between 5 and 15 feet higher than the top of the lowest sandstone in the Lampson quarry. The creek is only about 50 feet west of the well and about 8 feet lower than the floor of the derrick. The fall in Mosquito Creek from the bridge at Brown's farm to where it enters the Mahoning River at Niles is only between 7 and 8 feet, as determined by survey. The well is a flowing one, the water of which is said to be pure, but it has a slightly salty taste. A sample of the drillings from a depth of more than 2,800 feet was seen, which consisted of chips of moderate coarseness partly of light and partly of dark gray color with the lithologic appearance of limestone, which effervesced strongly in cold HCl, showing that it is a limestone. A somewhat gen-

eral record of the well was furnished by Mr. Brown, who watched it closely while it was being drilled. According to his information, at a depth of from 10 to 12 feet it entered quicksand which is about 75 feet thick, the lower portion of which is coarser with gravel at the bottom. Below the gravel is "soapstone", but not many feet of it before flaggy material was struck, which when ground up made a gray flour. In this rock between a depth of 110 and 125 feet was obtained the water, which is probably from the Berea grit. From this horizon "soapstone" and shale continued to a depth of more than 2,800 feet, when limestone was struck, which was called a very hard rock by the drillers. At a depth of 3,040 feet a white sand was reached, which is 15 feet or more in thickness. This sandstone is soft, since the bit was not battered as it had been while drilling in the limestone. Still deeper is black, gritty rock, in which the well stopped. This was called a black sand by the drillers, the drillings of which were finer than those of the limestone, with about the coarseness of building sand, in which the drillers reported grains of salt. It appears probable that this white sand reported at a depth of 3,040 feet represents the Sylvania sandstone of northwestern Ohio. Mr. Brown states that about a month after the well was finished oil appeared on the water which flowed out of the well, and this continued for some nine months. This oil may have come from the Berea grit, but Mr. Brown thinks it was from the bottom of the well. The following diagrammatic section shows about all the information obtained, that can be put in tabular form, concerning this well:

Section of Well on the Brown Farm Three Miles East of Warren.

0′		Mouth of well
	12′–14′	
14′		
	75′	Quicksand Gravel at bottom
89′		
	21′(?)	"Soapstone"
110′		
	15′	Water-bearing horizon which is apparently the Berea grit and its thickness may be greater than 15 feet
125′		
	2675′+	"Soapstone" and shale { Bedford and Ohio shales
2800′+		
	240′−	Devonian limestone
3040′		
	15′	Sylvania sandstone
3055′		
	16′	Black sand containing grains of salt
3071′		Bottom of well

To the east of the Brown farm is Howland Four Corners, some 60 feet higher than the mouth of the well. About one-fourth mile south of the corners is the farm of C. J. Lenox, on which is a well 63 feet deep that reaches a flagstone. The upper 9 or 10 feet of this well is in dirt, and then the remainder down to the flagstone is in "soapstone". This flagstone is considered by the owner to be the same as that in the Lampson quarry on the western side of Mosquito Creek. Another well near the house is 42 feet deep, but all in shale or "soapstone", and did not reach the flagstone. In a small run on the Lenox farm and 50 feet higher than the Four Corners, is brownish-gray, flaggy sandstone with a little coarser grain than the sandstone in the Lampson quarry. Thirty feet higher is a ledge of coarse-grained sandstone, which is of brownish color and rather micaceous. Loose on the slope of the hill, 20 feet higher, are blocks of the Sharon conglomerate, so that the upper sandstone in the run apparently belongs in the lower part of this formation. Unfortunately the elevation of the mouth of the Lenox well was not determined, but in a general way it seems probable that the base of the Sharon conglomerate is something like 140 feet higher than the top of the Sharpsville sandstone. As above stated, the thickness of this interval was not obtained with precision and may be slightly in excess of it. Professor H. P. Cushing has very kindly put in the writer's hands an unpublished manuscript entitled a "Geological Section through Ashtabula and Trumbull counties, Ohio," in which, for this general region, the thickness of the interval from the top of the Sharpsville sandstone to the base of the Sharon conglomerate is given as 130 feet.

Walnut Creek Section. — Bazetta Township lies to the north of Howland Township, and in its northeastern part is the village of Cortland, nine miles northeast of Warren. Walnut Creek, an eastern tributary of Mosquito Creek, flows through this village, and its banks from the upper part of the village to some distance below it afford interesting outcrops of the rocks of this vicinity. At the junction of Walnut and Mosquito creeks the ground is low and swampy, and no outcrops were found. Just above the bridge over Walnut Creek, however, on the first north and south road to the west of Cortland, thin-bedded buff sandstone occurs. This rock is much contorted, most of it thin-bedded and frequently rippled-marked. The upper surface of the top layer is very uneven and contains numerous pits due to the decomposition of iron pyrites and marcasite. In this particular there is a close agreement with the usual condition of the upper surface of the Berea grit. This sandstone is the upper portion of the Berea formation, some 13 feet of which is shown in the creek and on its banks. On the bank above the Berea grit, 14½ feet of black to bluish shales are exposed, all of which perhaps may be referred to the Sunbury, while at the top is a coarser and more arenaceous layer containing specimens of *Orbiculoidea.* This arenaceous layer was regarded as marking the upper limit of this zone, although

perhaps there is as much evidence in favor of drawing the line $4\frac{1}{2}$ feet higher at the base of a 4-inch sandstone. Still in the Mahoning River section above Warren, a zone of arenaceous shale occurs at the top of the Sunbury (?), some 13 feet above the top of the Berea grit, which has seemed to favor including all of this shale in one zone. The lower portion certainly has the lithologic appearance of the Sunbury shale, although it may be a question where the upper limit shall be drawn. Above the coarser layer are dark gray argillaceous shales.

The lower part of the Sunbury shale contains numerous specimens of *Lingula melie* Hall. The largest ones are about $10\frac{1}{2}$ mm. long and 6 mm. wide, in which the width is a little less in proportion to the length than in typical specimens of this species; still it is considered best not to separate them from those with the more nearly typical proportion in which the length is to the width about as 3 to 2.

There is a specimen which is larger than *L. melie* Hall, and has a sharper slope to the beak than in specimens of this species that have been examined. Its length is 13 mm. and width 8 mm., which is very near the size and proportion of the species described by Professor Herrick as *L. meeki*,[1] which he gave as 13 mm. long and 7.5 mm. wide. The Cortland specimen, however, resembles more nearly the figures of the species described by Professor Herrick as *L. atra*.[2] That species is a still larger form, however, since its length is given as 16 mm. and width as 10.5 mm. Its width then in proportion to its length is $\frac{17}{416}$ *greater* than that of the Cortland specimen, while the same comparison with *L. meeki* shows that it is $\frac{16}{416}$ *less* than that of the Cortland one, or in other words, the proportion of *L. meeki* to it is $\frac{1}{416}$ nearer than that of *L. atra*. The two figures, however, of *L. atra* given by Professor Herrick (Geol. Surv. Ohio, Vol. VII, pt. 2, pl. 22) do not indicate so large a form since fig. 6 is 15.8 mm. long and 10.4 mm. wide while fig. 5 is only 14.7 mm. long and 10.4 wide.

The next bank going up stream shows the following section:

Section on Walnut Creek below Cortland.

No.		Thickness. Feet.	Total thickness. Feet.
3.	Shales alternating with thin-bedded sandstones at base, thin sandstone of buff to gray color 4± inches in thickness	5	18
2.	Dark gray, argillaceous shale	$4\frac{1}{2}$	13
1.	At top, coarser arenaceous shale, below which is rather bluish, argillaceous shale. The top of this zone was considered as representing the upper limit of the Sunbury shale. Lower portion black shales, which on weathering are iron-stained. Not exposed down to the top of the Berea grit	$8\frac{1}{2}$	$8\frac{1}{2}$

[1]Bull. Denison Univ., Vol. IV, 1888, pp. 13, 18, pl. 10, fig. 31.
[2]Ibid., pp. 13, 16, pl. 10, fig. 30; or particularly fig. 6, pl. 22, pt. 2, Vol. VII, Geol. Surv. Ohio.

The above sections are down the creek not far below the railroad culvert. Just below the culvert is a bank of bluish-gray argillaceous shale 2+ feet thick, which occurs between two thin layers of sandstone.

Some 22 feet higher as determined by level, than the top of the Sunbury shale (?) is a bluish to light gray sandstone 23 inches in thickness. This is shown just northeast of the creamery on Front Street, not far above the railroad culvert, and is quarried to some extent for local use. Above are grayish to bluish argillaceous shales with alternating layers of sandstone from 1 to 4 inches thick. A little higher, as shown by the grading for Front Street, these argillaceous shales are bluer, weathering to a rusty color, and contain small calcareous to ironstone concretions. These higher shales contain a few fossils as *Lingula melie* Hall and *Chonetes* sp. The shales a little above the 23-inch sandstone are the most fossiliferous, and from these six species were collected.

The list is as follows:

1. Lingula melie Hall -- (a)
   The specimens are all rather small; but the proportion of length to width is generally about as 3 to 2, which is the typical proportion for this species as given by Hall. One specimen is $6\frac{1}{4}$ mm. long and 4 mm. wide; another is 6 mm. long and 4 mm. wide; while a third one, which is smaller, and near the size of the majority of the specimems from this locality, is 4 + mm. long and 2.75+ mm. wide, which is also about the standard proportion of 3 to 2.
2. Orbiculoidea herzeri Hall and Clarke -------------------------- (r)
3. Chonetes logani Norwood and Pratten (?) --------------------- (c)
   Specimens similar to those labeled as this species by Professor Herrick, which are in the Denison collection at Ohio State University. They have 44–46 lines (striæ) and perhaps 4 spines on a side.
4. Spirifer sp.-- (rr)
   Similar to the type of *Spirifer fimbriatus* (Con.) Hall.
5. Nuculites sp.--- (rr)
   Small specimen, with fine concentric lines (striæ) and distinct, straight, clavicular ridge.
6. Conularia sp. -- (r)
   Broken and quite imperfect specimens.

At the first bank on Walnut Creek above Front Street, the 23-inch sandstone stratum is shown in the bed of the stream, and above it is about 25 feet of bluish shales with thin sandstone layers, of which there are at least four conspicuous ones. These shales represent part of the Orangeville formation and closely resemble outcrops of them at Orangeville.

The upper portion of the Orangeville shale is rather arenaceous and fairly coarse up to the base of heavy to thin-bedded sandstone

of bluish-buff to bluish color. From the top of the 23-inch sandstone to the base of these heavy sandstones is about 38 feet, according to the barometer, and the contact of the Orangeville formation and the Sharpsville sandstone is well shown on both the east and west banks of Walnut Creek below the High Street bridge. Higher on each side of the creek are old quarries where the sandstone has been worked. The grain is considerably finer than that of the Berea grit and the rock does not crumble so readily. The contact of the Orangeville formation and the Sharpsville sandstone is shown in Plate LXII. The layers of Sharpsville sandstone are conspicuous, forming the upper part of the bank, below which are the shales of the Orangeville formation, with an occasional thin sandstone. One rather prominent sandstone stratum in the midst of these shales is shown only a few feet above the base of the section.

The contact of the Orangeville formation and the Sharpsville sandstone is again shown in the lower half of the cascade in Walnut Creek under the High Street bridge. There are 5 feet of the upper Orangeville shales, which are somewhat sandy and of bluish color, shown in the lower part of the cascade, above which and on the creek bank, 16½ feet of the Sharpsville sandstone occurs. The layers of sandstone at this locality are either bluish or very bluish-gray in color, and there are some partings of bluish-gray shale.

The above described outcrops along Walnut Creek and its vicinity may be condensed into the following continuous section:

Section of Walnut Creek at Cortland.

No.		Thickness. Feet.	Total thickness. Feet.
7.	*Sharpsville sandstone.* Bluish, fine-grained sandstones, which vary from thin to heavy-bedded layers, with occasional partings of bluish-gray shale. Seventeen feet shown at this locality	17	107
6.	Top of *Orangeville formation.* The upper shales are rather arenaceous and coarse, 5 feet or more in thickness; below which are bluish, partly argillaceous shales, with an occasional thin sandstone stratum. These shales are somewhat fossiliferous, especially in the lower part in which *Lingula melie* Hall is quite abundant, and is associated with some other species	38	90
5.	Bluish to light gray, compact sandstone 23 inches thick	2 –	52 –
4.	Grayish shales, alternating with thin sandstones, of which one at the base is about 4 inches thick	18	50
3.	Dark gray, argillaceous shale	4½	32
2.	At the top is a rather sandy, grayish and somewhat coarser zone containing fossils, as *Orbiculoidea.* Next lower, are rather bluish shales, below which are thin, fissile, black shales as a rule, although some are a little bluish in color. On weathering they are frequently much		

PLATE LXII.

Contact of Orangeville formation and Sharpsville sandstone on Walnut Creek, Cortland.

No.		Thickness. Feet.	Total thickness. Feet.
	iron-stained, and in the lower portion Linguloid fossils are abundant, especially *Lingula melie* Hall. At least the lower portion of this zone apparently represents the *Sunbury shale*	14½	27½
1.	*Berea grit.* Mainly thin-bedded, buff sandstone, the layers of which are much contorted and frequently ripple-marked. The upper surface very uneven, with numerous pits, due to the decomposition of iron pyrites. About 13 feet is shown and the bottom of the formation is not reached	13	13

The above section is one of the longest continuous rock exposures noted in this region, and is important in giving the limits of the Orangeville formation, together with exposures of nearly all the rocks composing it. Its entire thickness as determined in part from leveling and partly by the barometer is 77 feet, which is less than its usual thickness in Crawford County in western Pennsylvania, as reported by Dr. I. C. White,[1] or in the Cuyahoga Valley, as determined by the writer. Both the lower and upper contacts of the formation are clearly and sharply shown on the creek, so that there can be no question concerning its limits. At this locality Professor Cushing gave the thickness of the Berea shale, which is the same formation, as 55 feet. The flaggy sandstones succeeding it clearly belong in the lower part of the Sharpsville sandstone of Pennsylvania, which in Crawford and Mercer counties, the ones bordering the northeastern part of Ohio, is the terrane immediately succeeding the Orangeville formation.

When describing the Berea grit in the vicinity of Cortland, Dr. Orton wrote as follows: "It is always overlain by a thin but very black fossiliferous bed of the Berea shale. An excellent section is furnished in the banks and the bed of Walnut Creek, within the limits of the village of Cortland, and a half-mile below. At the junction of Walnut and Musquito creeks, the flag-rock that makes the upper bed of the Berea is found in the bed of the stream. It is covered by 8 feet of Berea shale, very black and crowded with its characteristic fossils."[2] There appears to have been some mistake in the location of this section, for as already stated, the ground at the junction of these creeks is low and swampy, while the outcrop of Berea grit and Sunbury shale is some distance up Walnut Creek to the east of the north and south road.

Cortland Well.—In 1903 a well was drilled on the Edward Hadsell farm, five-eighths of a mile north of Cortland village, which on

[1]Second Geol. Surv. Pa., Q^4, 1881, p. 89, where it is stated to be "120′ thick on the Shenango river at Sharon, 120′ thick on Cussewago creek, usually 100′ throughout Crawford county, and in very few places less than 60′" although on the "Generalized section" on p. 66 its thickness is given as 75 feet.

[2]Geol. Surv. Ohio, Vol. VI, 1888, p. 331.

account of its depth is important from a stratigraphic standpoint. Unfortunately only a comparatively small number of samples was saved from this well, so that its record is not as accurate or complete as desired. Again there is a difference in the several reports as to the depth at which the Devonian limestone was reached as well as in some other particulars of the record. On a fair day with an interval of only 32 minutes between the readings, the barometer gave the same reading at the mouth of the Cortland well as at the top of the Orangeville formation in Walnut Creek, Cortland. Apparently the mouth of the Cortland well is near the contact of the Sharpsville sandstone and the Orangeville formation. It may have commenced in the horizon of the lower part of the Sharpsville sandstone, but the writer inclines to the view that it is in the Orangeville formation and near its summit. If this be true, then apparently this well and the one on the Brown farm east of Warren began at about the same geological horizon.

Mr. James Hayhusk lives on the farm adjoining that of Mr. Hadsell and he followed very carefully the drilling of the well. He took certain samples from the drillings, the depths of which were obtained from the well measurements or by counting the revolutions of the "bull wheel"; these he divided with the writer and gave him in addition a partial record of the other portions of the well. According to Mr. Hayhusk, the well passed through from 10 to 15 feet of dirt and from 50 to 60 feet of "shell to soapstone" when a "flag-rock" was reached which contained some water, but was not very thick. The 50 to 60 feet of "shell to soapstone" is regarded as the thin sandstones and shales of the Orangeville formation, while the "flag-rock" is the Berea grit, the top of which was reached at a depth of from 60 to 75 feet. It will be remembered that the Orangeville formation is 77 feet thick on Walnut Creek in Cortland, and consequently it would appear that this well began in the upper part of that formation and probably well toward its top. The following samples with their depths were given the writer by Mr. Hayhusk:

Section of Cortland Well.

Depth. Feet.	Description of Sample.
2840.	Top of the limestone according to Mr. Hayhusk. Light gray rock, which effervesces strongly in cold HCl. Devonian limestone (Niagara limestone of drillers).
2960.	Drab to dark gray limestone, which effervesces rather more slowly in cold HCl than the first sample.
2995.	Sample not seen, but reported as a porous sand-rock, from which several barrels of oil were obtained. This oil is very fluid (light), with greenish color in mass; but somewhat amber when held toward the light, and in general appearance similar to the oil from the Andover well. Mr. Hadsell gave the depth of this sandstone as 3,000 feet, and showed a sample composed of grains of white quartz sand.

Depth. Feet.	Description of Sample.
3071.	Chips mainly light gray to drab limestone, which effervesce strongly in cold HCl. A few dark colored chips.
3120.	Fine grains of dark gray limestone, which effervesce slowly in cold HCl.
3150.	Dark gray chips, which effervesce very slowly in cold HCl.
3170.	Rock called the Clinton by the drillers. No sample.
3350.	Rock salt in small grains. Reported as 15 feet thick by Mr. Hayhusk, extending from 3350 to 3365 feet.
3464.	Rock salt in larger crystals than the previous sample, and nearly pure white in color. Reported as 91 feet of clear rock salt by Mr. Hayhusk, extending from 3464 to 3555 feet.
3555.	Rock salt, small grains like those from a depth of 3350 feet, and reported as "bottom salt" by Mr. Hayhusk. Below the rock salt it was reported as hard, drillings fine, and progress of well slow.
3600.	Brownish-gray limestone, which effervesces strongly in cold HCl. This is the last sample saved, and reported as the bottom of the drilling by Brackly, the first driller. Mr. Hayhusk stated that then the Walle Bros. took the well and drilled 142 feet deeper, making its total depth 3742 feet.

Mr. Hadsell showed the writer samples of black shale with a streak varying from brownish to light color, but the depth was not known. He reported the top of the limestone as 2,500 ± feet in depth, and showed a sample of drillings from its upper part which consisted of chips of light gray limestone effervescing strongly in cold HCl.

The Warren well on the Brown farm began near the same horizon as the Cortland well, perhaps a little higher stratigraphically, and the top of the Devonian limestone was reached at a reported depth of more than 2,800 feet. This agrees closely with the depth of 2,840 feet reported by Mr. Hayhusk for the Cortland well; therefore, the depth at which he reported the top of the limestone is regarded as more accurate than the 2,500 ± feet given by Mr. Hadsell.

Since the above information was secured Dr. Bownocker has published the following section of this well:

	Thickness. Feet.	Total depth. Feet.
Drift	40	40
Shale	60	100
Berea grit	160	260
Bedford and Ohio shales	2396	2656
Corniferous and Monroe formations	583	3239
Rock salt	12	3251
Limestone	5	3256
Rock salt	2	3258
Limestone	3	3261
Rock salt	10	3271
Limestone	50	3321
Rock salt	29	3350
Limestone	10	3360
Rock salt	52	3412
White shale	18	3430

	Thickness. Feet.	Total depth. Feet.
Limestone	35	3465
Rock salt	10	3475
Limestone	27	3502[1]

According to this record the top of the Devonian limestone was reached at a depth of 2,656 feet, instead of 2,840 feet as reported by Mr. Hayhusk, or 184 feet higher. The interval from the top of the Devonian limestone to the top of the salt is 510 feet, according to Mr. Hayhusk, and 583 feet according to the record furnished Dr. Bownocker. Again, the total thickness of the salt is 106 feet, according to Mr. Hayhusk, and 115 feet in the latter record. At any rate, it appears to be certain that the thickness of the interval between the base of the Sharpsville sandstone and the top of the Devonian limestone is probably as great as 2,656 feet, and perhaps reaches as great a thickness as 2,840 feet.

Mecca Township. — To the north of Bazetta Township, in the northeastern part of which is the village of Cortland, is Mecca Township. In this township is one of the old oil fields of the United States, opened in 1861, which was described to some extent by Read in his report on Trumbull County.[2] This field produced an excellent lubricating oil, but for many years the production has been very small. The writer visited this locality in August, 1901, but it was many years after the principal exploration for oil was finished and not much additional information was obtained. The horizon of the oil as stated by Read and others is in the Berea grit, which outcrops at various localities on ridges to the west and east of Mosquito Creek, which flows across the township from north to south, slightly east of its central part. On the H. L. Cowdery farm, nine miles north of Warren and one and one-half miles south of West Mecca, an oil shaft was sunk many years ago. Below the shaft is a small quarry, which was filled up for about 10 feet. On its bank is coarse-grained friable sandstone, which is said to be the "bogus sandstone" of the drillers. Some of the layers apparently from the quarry consist of coarse-grained sandstone with ripple-marks. The driller (Gilman) stated that all of the sandstone in this shaft and quarry is Berea, and that there are two oil crevices in it, one at a depth of 45 feet and the other between 52 and 54 feet. The rock from the shaft and quarry so far as seen is all a coarse-grained sandstone, which lithologically is like the Berea grit. There are some blocks of red and gray banded rock on the dump from the shaft. According to Mr. Gilman there are two oil-producing sands in the shaft on the Cowdery farm, one 45 feet down and the other 52 feet. These evidently correspond to what Mr. Gilman termed the crevices. Mr.

[1]Am. Geologist, Vol. XXXV, 1905, p. 375. Geol. Surv. Ohio, 4th ser., Bull. 8, 1906, p. 39.
[2]Geol. Surv. Ohio, Vol. I, pp. 505-508.

Gilman also reported that about 18 feet down the shaft is the sandstone which was quarried on the Cowdery farm below the shaft and called the "bogus rock." This "bogus rock" is very oily and is noted in the different wells. It was also reported that the Berea commenced in the shaft at a depth of 18 feet and continued to the lower oil horizon, which is 52 feet down, below which there is a white sand which will go to a depth of at least 65 feet. The well drilled near the Cowdery shaft is stated to be 1,000 feet deep, and below the oil sand it was all shale reported as blue, brown, black and even some red in color.

A well on the Thomas Park farm, one mile north of the Cowdery farm and Mott's Corners, is reported to have been drilled 2,200 or 2,300 feet deep, but Mr. Park said that perhaps it was not more than 1,800 or 1,900 feet. He stated that the lower crevice of the Mecca oil is 62 feet down in this well. The casing is 215 feet, and the remainder of the well was dry. This well was put down by a stock company and drilled by Will M. Dabney, of No. 2016 Detroit Street, Cleveland, Ohio. The first oil was found in a spring on the Wagner farm, opposite the deep well on the Park farm.

Mr. Gilman reported that most of the oil was obtained from wells near the highway between Mott's Corners and West Mecca. Along the highway the deepest oil came from a depth between 49 and 52 feet; a third of a mile to the west it is between 63 and 65 feet, while to the east of the creek it varies from 65 to 80 feet. This apparently shows an anticlinal fold with the summit near the highway from which the greatest quantity of oil was produced.

At West Mecca the first crevice (as the residents term it) is reported at a depth of 31 or 32 feet and the second one 42 feet. Below the oil rock is a white sand which extends down to 85 or 90 feet and perhaps to a depth of 100 feet.

At Champion, which is in the township to the west of Bazetta and north of Warren, it is reported that in the upper part of the well there was shale, sand (Berea) was struck at 54 feet, then at 70 feet an oil sand from 4 to 6 feet thick, below which was a soft, white sand down to 134 feet. This apparently indicates a thickness of 80 feet for the Berea grit, which is identical with the measured section on Mill Creek in Mesopotamia Township, some 14 miles to the northwest. Below the Berea grit was blue shale and still deeper brownish shale was noted, the well continuing in shale to a depth of 500 feet. It was also reported that the sand was reached in a well on the Len Pearce farm, about 3 miles north of Warren, at a depth of 56 feet.

Orangeville Sections.—It seems more desirable to the writer to continue the description of the Carboniferous formations to the eastward from the Mosquito Creek Valley, instead of continuing to the northward and describing the Devonian formations of Ashtabula County. Therefore, instead of next considering sections in the townships in

the northern part of Trumbull and southern part of Ashtabula counties there will be considered together, to a certain extent, the eastern tier of townships in these two counties with the adjacent ones in western Pennsylvania which are underlain by Carboniferous formations, principally those belonging in the Mississippian series. To the east of Mosquito Creek is the Pymatuning, and to the east of this is a comparatively high divide in the townships of Vernon and Kinsman in Trumbull County and Williamsfield and Andover in Ashtabula County. This ridge is well dissected by streams which afford a number of very fair geological sections. The first one to be considered is in Orangeville, a small village in the Pymatuning Valley on the State line, located partly in Trumbull County, Ohio, and partly in Mercer County, Pennsylvania. The Ohio part of the village is located in the northeastern part of Hartford Township, the greater part of which is underlain by rocks of the Pennsylvanian series.

On the southern bank of Pymatuning Creek, just below the bridge and dam in Orangeville on the Pennsylvania side, is a bank composed mainly of bluish-gray shales which gives the following section:

Section at Orangeville.

No.		Thickness. Feet.	Total thickness. Feet.
5.	Dark gray to bluish-gray, argillaceous shales, which contain some small ironstone concretions	$10\frac{1}{2}$	$21\frac{5}{6}$
4.	Bluish-gray sandstone, weathering to a rusty color, from 6 to 8 inches thick	$\frac{1}{2}$+	$11\frac{1}{3}$
3.	Grayish to bluish-gray shales, argillaceous and slightly gritty, containing some specimens of *Chonetes* and *Lingula*	$4\frac{5}{12}$	$10\frac{5}{6}$
2.	Bluish-gray sandstone, which weathers to a rusty color	$\frac{5}{12}$	$6\frac{5}{12}$
1.	Rather bluish, argillaceous shales, which near the creek level are more arenaceous and bituminous, containing numerous specimens of *Lingula melie* Hall	6	6
	Creek level.[1]		

It was thought when the above section was first published that the majority of the specimens from this shale (zone No. 1 of section) belonged to *Lingula cuyahoga* Hall, because the proportion of length to breadth is about as 5 to 3 as stated by Hall in his description of this species. The measurements of several specimens is as follows:

Length.	Breadth.
9 mm.	$5\frac{1}{2}$ mm.
11 "	$6\frac{1}{2}$ "
10 "	6 "
9 "	$5\frac{1}{2}$ "
$11\frac{1}{2}$ "	$7\frac{1}{2}$ "
$11\frac{1}{2}$ "	$6\frac{1}{2}$ "
$10\frac{1}{2}$ "	6 "

[1]This section was also published in the Journal of Geology, Vol. X, 1902, pp. 305, 306.

The proportion of length to breadth of the above specimens is not far from 5 to 3 or on the other hand of 3 to 2, which is that of *L. melie* Hall. It was found, however, when the type specimens of these two species were studied in the American Museum that *L. cuyahoga* Hall is a rather quadrate form with a length of 15 mm. and a width of 10 mm. for the specimen represented by fig. 5, pl. 1, Vol. IV, Pal. N. Y., which is the proportion of 3 to 2 or that of *L. melie* rather than of *L. cuyahoga*, according to Hall's description. The size, however, is larger than that of the types of *L. melie*, which are as follows for the two specimens illustrating the original description of this species: fig. 3, length 11 mm., width 7.2 mm., and for fig. 4, length 9.5 mm., width 5.5 mm. It will be seen from the above measurements that the Orangeville specimens agree very nearly in size with these type specimens of *L. melie*, from which perhaps they ought not to be separated. A smaller number of specimens have almost the exact proportion of 3 to 2 for that of the length to the breadth of the shell. One specimen is 9 mm. long and 6 mm. wide, which gives the exact ratio of 3 to 2. These are the specimens which were given in the former list as *L. melie* Hall.

In zone No. 3 of the section, specimens of a *Lingula* are common, which may probably be referred to *L. melie* Hall. The length of one is 5.5 mm. and its width 4.75 mm., which is much nearer the general size of this species than of *L. cuyahoga* Hall, although the proportion of length to width is a little nearer that of the latter species. Imperfectly preserved specimens of *Orbiculoidea* occur rarely, on which the apex of the brachial valve is apparently rather high, and which may be listed as *O.* cf. *herzeri* Hall and Clarke. Specimens of *Chonetes* are common, which closely resemble others in the Denison collection at Ohio State University, which were labeled *C. planumbonus* Meek and Worthen by Professor Herrick. The Orangeville specimens have from 40-50 lines (striæ), which have bifurcated toward the margin. One specimen shows three curving spines.

All of the above shales weather to a rusty color on exposure and contain fossils, as *Chonetes* and *Lingula*, the latter being much more numerous than in the corresponding shale in the Cleveland region.

These rocks were named the Orangeville shales by Dr. I. C. White, who stated that the name was used "merely for the convenience of avoiding in this report a premature discussion of the question of its identification with the Waverly black shales of Andrews, or lower member of the Cuyahoga shale of Newberry."[1] He described it as "a group of shales prevailingly blue, but often rusty or reddish-brown on exposed surfaces, always more or less argillaceous, seldom exhibiting sandy layers more than six inches thick; and containing considerable quantities of scattered iron ore balls," with a thickness of about 75 feet at Orangeville.[2] Under the description of Pymatuning Township, Mercer County,

[1]Second Geol. Surv. Pa., Q^3, 1880, p. 63.
[2]Ibid., p. 63.

in which the eastern part of Orangeville is located, is the following account of the cliff below the Orangeville Street bridge where, it is stated, 40 feet of rock is exposed in a cliff: "The horizon is *300 feet below that of the Sharon coal,* and therefore under the *Cuyahoga shale.* The upper portion of this exposure consists of reddish-gray shales, interstratified with thin black layers; but down near the creek level the shales begin to grow much finer and darker; and just below the mill-dam fragments of a dark bluish fine-grained shale in the water bed are perfectly filled with *Discina pleurites* and *Lingula melie.* This can hardly be the *Cleveland shale* of Dr. Newberry."[1] In the succeeding report Dr. White spoke of the Orangeville shales as "these bottom deposits of the *Cuyahoga formation* of Ohio."[2] Dr. Orton stated that "White's Orangeville shale is an equivalent of our Berea shale."[3]

In the section of the bank described above it will be seen that there is no horizon shown that could be taken for either the upper or lower limit of the formation. It, however, appears probable that Dr. White regarded the shales, which occur on the Mahoning River above the water works at Warren and which have already been described in this bulletin, as belonging in this formation, since he has cited the locality at Warren as one where fossils are very abundant in it. He also stated that the shale is darker than in Crawford County and some of the thin layers are bituminous,[4] which description agrees with the writer's observations of the Warren locality. In the Mahoning River section above Warren it has been shown that these black shales rest directly upon the Berea sandstone, and consequently there is a sharp line of separation between the Berea sandstone and Orangeville formation. The Orangeville shales, as described by Dr. White, are limited above by the Sharpsville sandstone, and in the section on Walnut Creek in Cortland the contact between the Orangeville formation and Sharpsville sandstone has already been described. The evidence appears to be conclusive that these bluish to blackish shales which are exposed along the State line, limited below by the Berea sandstone and above by the Sharpsville sandstone, may be readily followed westward to the Cleveland region and beyond. It also appears to mark a lithologic unit for areal work, and has been accepted by the writer as a formation in the various sections that have been described in this territory. Many of these sections give a much better idea of the details and character of the formation than is to be obtained at the locality where it was named. In a general way it represents the lower half of the terrane to which Dr. Newberry gave the name Cuyahoga formation; but as has already been shown in the de-

[1]Ibid., p. 160.
[2]Ibid., Q^4, 1881, p. 89, and see p. 90 f. n.
[3]Geol. Surv. Ohio, Vol. VII, 1895, p. 33.
[4]Second Geol. Surv., Pa., Q^4, p. 90 and f. n.

scription of the Cuyahoga River Valley, Dr. Newberry's description was apparently drawn up mainly for the sandstones and arenaceous shales shown in the gorge of the river below Cuyahoga Falls, while he seems to have failed to note particularly the soft shales forming the lower portion of the terrane, which are not very well exposed on the river bluffs but are admirably shown in some of the tributaries of the river.

On the farm of Charles Troutman about two miles north of Orangeville is an outcrop of the Sharon conglomerate, the base of which is about 270 feet higher than Pymatuning Creek at Orangeville. One part of this ledge is a quarry which in 1901 was worked by Melvin and Echenrode. The quarry furnished the following section:

Troutman Quarry.

No.		Thickness. Feet.	Total thickness. Feet.
4.	Top of stone glaciated, as shown by the smooth and striated surface. This course splits into several layers	$1\frac{7}{12}$	18
3.	Cross-grained, quartzose sandstone varying to grit. Very light gray to whitish in color, but weathers to a buff and brownish color due to iron. Massive course used largely for bridge stone. On one side of the quarry a shale parting appears near its middle	6	$16\frac{5}{12}$
2.	Less desirable sandstone	$4\frac{1}{6}$	$10\frac{5}{12}$
1.	Contact of sand and conglomerate. The matrix of the conglomerate is about the same as that of the sandstone above, and in it are imbedded numerous large, white, quartz pebbles, and a few of other colors were also noticed. The pebbles are smaller than in the exposures of this conglomerate shown in the Cuyahoga gorge near Akron, but it is still an excellent example of a conglomerate	$6\frac{1}{4}$	$6\frac{1}{4}$

There is at least nine feet of conglomerate below that just described in the quarry, making a thickness of 15 feet for this stratum, which gives about 27 feet for the thickness of the Sharon conglomerate exposed at this locality, but the hill runs up to a height of 85 feet above this exposure. This 15-foot ledge of conglomerate is shown at the spring and cave which are near the quarry. The pebbles are more or less perfectly rounded, the bulk of them not over the size of a pea, though there are many that are smaller, and also some that are larger, although hardly any are the size of a hazelnut. The pebbles are mostly of white quartz with an occasional colored one, the colored ones being most frequently of rose quartz.

On the western slope of the hill there is a ridge 50 feet below the conglomerate at the spring and a coarse-grained sandstone, shown at an old opening, is probably the Shenango. Then there is a gradual slope to about 130 feet below the base of the conglomerate when an-

other ridge is reached, probably the Sharpsville sandstone, but along the old road to the west (now abandoned) no exposures were seen.

Orangeville Well. — In 1902 a well was finished in Orangeville, Ohio, and the author is indebted to Messrs. W. J. Apthorp and J. D. Burnett of that town for information concerning it and samples of the drillings. The mouth of the well is in the creek valley above the State Street bridge, estimated as about 6 feet higher than the milldam, which would make it about 10 feet higher than the base of the shales exposed on the creek bank below the dam. The creek alluvium in the well is reported as 17 feet thick and at that depth shale was struck. The first sample submitted to the writer from a depth of 42 feet is reported as the first sand struck in the well, and is considered the top of the Berea grit. The sandstone is composed mainly of light gray silicious and very micaceous sandstone with an occasional grain of iron pyrites, and lithologically closely resembles the Berea grit. Mixed with the sandstone chips is an occasional one of black shale, evidently from above the sandstone. This light gray sandstone is reported to continue to a depth of 122 feet, and a sample from 50 feet and another from between 57 and 117 feet are from a light gray, very silicious sandstone. A sample from 117 to 122 feet is composed of fine light gray to white quartz sand with some grains of iron pyrites, and its bottom is thought by Mr. Burnett to represent the base of the Berea grit. Immediately below this Mr. Apthorp reports 3 feet of shale, but the sample from 122 to 164 feet is composed mainly of quartz sand. Mr. Burnett, however, reported that at 122 feet the drill entered a softer sand. A sample from 164 to 170 feet is composed of bluish argillaceous shale with a white streak and bluish-gray or gray arenaceous shale to thin micaceous sandstone. From a depth of 170 to 415 feet the chips are mostly dark gray in color and apparently mainly from arenaceous shale. In this record there is some uncertainty as to what should be considered the base of the Berea grit. If the line is drawn at the top of the 3 feet of shale reported at the depth of 122 feet, then the Berea will have a thickness of 80 feet. The sample, however, from 122 to 164 feet is composed mainly of rather large pieces of quartz sand and is apparently from a massive sandstone. If this lower sandstone be classed in the Berea grit, then the formation will have a thickness of 122 feet. Specimens were seen to a depth of 1,715 feet, and the deeper ones are mainly from bluish to grayish argillaceous shales, together with some from grayish arenaceous shales and thin grayish sandstones apparently in the Chagrin formation. The samples show no indication of the black Cleveland shale, so that it is impossible to give the base of the Bedford or top of the Chagrin formation in this record.[1] Later Mr. Apthorp said he thought the well was drilled

[1]Part of this data was first published in the Journal of Geology, Vol. X, 1902, pp. 308, 309.

to a depth of 2,200 feet without reaching the limestone. The detailed notes concerning a part of the samples of drillings from this well are given below.

Record of Orangeville Well.

No.	Depth. Feet.	Description of sample.
	42.	Mainly light gray, silicious sandstone, which is very micaceous, with an occasional grain of iron pyrites. An occasional chip of black shale from above, and some of the chips are fairly coarse. *Berea sandstone.*
00.	50.	Mainly light gray, silicious chips, like those of the sample above; but some are of darker gray color.
1.	57–117.	Light gray, very silicious sandstone, some of the chips rather large.
2.	117–122.	Fine, light gray to white quartz sand, with some grains of iron pyrites. Three feet of slate reported at the base of this zone; but no sample was sent.
3.	123–164.	Largely quartz sand in rather large fragments. A little of it is of rose color, and there were a few chips from above. (Mr. Burnett reported "through Berea at 122 feet into a softer sand.") This probably is the Cussewago sandstone, and its base is probably that of the Berea formation.
4.	164–170.	Bluish, argillaceous shale, with white streak to bluish-gray or gray, arenaceous shale or thin, micaceous sandstone.
5.	170–280.	Rather dark-gray, mainly arenaceous chips, probably from shale. "Slight show of gas at 200 feet." Burnett.
6.	280–320.	Mainly dark gray, micaceous, arenaceous shale. Some chips of bluish-gray color of similar rock. Gas somewhat strong at 300 feet.
7.	320–355.	Mainly dark gray to bluish-gray, finely arenaceous shale. Some chips light gray and more silicious, with larger grains of quartz.
8.	355–390.	Dark gray to bluish-gray, finely arenaceous chips from shale.
9.	390–410.	Bluish, argillaceous shale, mixed with light gray, arenaceous chips of sandstone or arenaceous shale.
10.	410–415.	Light gray, very silicious chips, composed largely of fine grains of quartz, and apparently from a sandstone.
44.	1715.	Series of samples of about the same lithologic character, the last one received from a depth of 1715 feet. This sample consisted of fine-grained, light gray, arenaceous shale to sandstone, mixed with chips of olive, argillaceous shale. The *Chagrin formation.* The Devonian limestone was not reached.

The data furnished by the Orangeville well taken in connection with the barometric section from the level of Pymatuning Creek to the Sharon conglomerate on the Troutman farm north of Orangeville, apparently show that in the vicinity of Orangeville there is an interval of about 300 feet between the base of the Sharon conglomerate and the top of the Berea grit. The thickness of this interval agrees fairly well with that given by Professor Cushing in his section

in Ashtabula and Trumbull counties near the Pennsylvania line, which is 235 feet.[1]

An examination of Dr. Orton's description of the well records of this region leads the writer to conclude that he referred all the sandstone at this horizon to the Berea grit. Dr. Orton reported the Berea grit "to have a thickness of 100 feet or even more"[2] in the Mecca oil field to the northwest of Orangeville in the northern central part of Trumbull County. In the wells near Youngstown, which is in the northern part of Mahoning County and southwest of Orangeville, the Berea is given as from 150 to 160 feet thick "with a thin bed of shale interstratified about half way down."[3] Still farther south in the East Liverpool gas field in the southeast corner of Columbiana County in the Ohio River Valley, Dr. Orton stated that "the Berea grit ranges in this territory from 60 to 120 feet in thickness".[4] From a well near Sharon in the western part of Mercer County, Pennsylvania, about seven miles south of Orangeville, the Pennsylvania geologists have reported a "white sharp sandstone" 75 feet thick, the top of which is 313 feet below the base of the Sharon conglomerate,[5] which Mr. Carll regarded as probably identical with the Pithole grit of Pennsylvania on the one hand and with the Berea grit of Ohio on the other.[6]

Section West of Sharon, Pa.—To the east of Hartford Township, Trumbull County, Ohio, is Pymatuning Township, of Mercer County, Pennsylvania, to the south of which is Hickory Township, in which are the towns of Sharpsville and Sharon. These two townships are also crossed by the Shenango River and contain the standard sections of the Sharpsville sandstone, Shenango sandstone and shales and Sharon conglomerate of the Pennsylvania nomenclature. This region was visited for the purpose of studying these formations at their typical localities, and the divide to the west of the Shenango River and Sharon was also studied for outcrops of these formations. About two and one-half miles southwest of Sharon and about a mile west of the State line the Shenango sandstone was found in the Rose and Son quarry, the top of which is about 115 feet higher than the Erie station in Sharon. About 50 feet higher is the base of the Sharon conglomerate, also shown in another quarry operated by Rose and Son. This was an old quarry which had not been worked for a long time but was reopened in 1900 by this firm. They had a mill for sawing the stone and a dummy line down the hill to the brick works, which used the Shenango shale for raw material. The section of this quarry and subjacent rocks is as follows:

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[1]Proc. Am. Assoc. Adv. Sci., Vol. XXXVI, 1888, p. 214.
[2]Geol. Surv. Ohio, Vol. VI, p. 331.
[3]Ibid., pp. 402, 403.
[4]Ibid., p. 333.
[5]Second Geol. Surv. Pa., Q^4, 1881, p. 70; also see I^3, 1880, Atlas, pl. IV, fig. 3, where the interval is given as 310 feet; Q^2, 1879, pp. 298, 303; and Q^3, 1880, p. 119.
[6]Ibid., I^3, p. 93.

Section of Quarry and Lower Rocks West of Sharon.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Sharon conglomerate.* Top of rock glaciated, as shown by smooth, striated surface. The upper $2\frac{1}{2}$ feet consists of layers of pebbles alternating with a grayish sandstone which contains a few pebbles. In places this upper $2\frac{1}{2}$ feet is whitish, quartzose, coarse-grained sandstone without pebbles. The conglomerate is immediately above the quarry cliff and is a very pebbly rock, the pebbles mostly white quartz, ranging in size from that of a pea to that of a hickory nut	19	79
2.	*Shenango shales.* The upper part consists largely of sandstones which are thicker than the lower ones, but much shattered, and are used for rubble, cellar walls, etc. Bluish shales, alternating with fairly thin-bedded, bluish sandstones. These shales and thin sandstones form about the lower two-thirds of the cliff. The shales are used for brick	49	60
1.	*Shenango sandstone.* Massive, coarse-grained, quartzose sandstone, which is rather friable in the fingers. The upper part is brownish to buff-color, with numerous iron spots, and about the lower $3\frac{1}{2}$ feet is blue in color. The sandstone which rests on a blue shale and varies in thickness from 11 to 14 feet makes dimension stone, and is also sawed into curbing	11+	11+

The Sharon conglomerate as shown at this locality is lithologically similar to that on the Troutman farm to the north of Orangeville, except that part of the pebbles are larger. They are mostly ovoid or rounded, but not flattened, and there is an occasional jasper pebble. The dip of the rocks at this locality is to the south. This may be regarded as a characteristic section of the Sharon conglomerate near its typical locality, where it was described by Dr. White as having a thickness of about 20 feet and composed of "two layers, of equal thickness, and without interval" as exposed in the vicinity of Sharon. The upper layer he described as a "moderately coarse sandstone, almost snow-white" in color, while the lower one consists of "a mere mass of pebbles loosely cemented in a matrix of coarse bluish gray sand of various sizes but none larger than a large hickory nut and most of them rounded or waterworn".[1] Dr. White stated in a foot note on the same page that it was called the Ohio conglomerate in Report Q^2 "because it is the only stratum recognized by the Ohio geologists as representing *the conglomerate* in that state." This name, however, was a synonym at that time, since the geologic term Ohio shale had been given by Andrews in 1870, and in the same foot note Dr. White stated that "the term cannot be applied in Pennsylvania without producing

[1]Ibid., Q^3, p. 56.

confusion." It appears, however, that the U. S. Geological Survey has recently accepted Olean as the name of this conglomerate for northwestern Pennsylvania. Mr. Butts has written as follows: "The names 'Garland' and 'Sharon' have also been applied to this stratum [Olean conglomerate member of the Pottsville formation], on the supposition that it is the same as the quarry rock at Garland and the conglomerate at Sharon. The name Olean has priority, however, as it was used by Ashburner before either 'Sharon' or 'Garland' was used and is, furthermore, more appropriate on account of the fine development and exposure of the conglomerate at Rock City near Olean [New York]."[1] Later, apparently the same conclusion is expressed by Mr. Shaw who, in referring to the Olean conglomerate, states that it "is the lowest member of the Pottsville in northwestern Pennsylvania."[2]

In reference to the correlation of the Shenango sandstone with the Ohio formations, it is interesting to note that as early as 1881 Dr. Orton stated that "The Logan group of my scale certainly has its extension in the Shenango sandstone of western Pennsylvania and the beds that separate the latter from the Sharon conglomerate."[3]

Mr. Charles Butts in discussing the "pre-Pennsylvanian stratigraphy" of western Pennsylvania and eastern Ohio, wrote that "The Shenango Sandstone is regarded as the basal part of the Burgoon ('Big Injun') sandstone of Pennsylvania, and as the equivalent, in part at least, of the Black Hand formation of Ohio, the Burgoon as a whole being regarded as the equivalent of the Black Hand and Logan formations"[4]

Finally, Professor Schuchert in his "Table of Mississippic formations" has indicated the correlation as follows: "Logan (Shenango shale of Pennsylvania) Black Hand (Shenango of Pennsylvania)."[5]

To the southwest of the large quarry a new one was opened in 1901 in the Sharon sandstone, a light gray quartzose sandstone, which when very pure is almost white in color. However, much of the stone from the presence of iron is yellowish to brownish when weathered. In August, 1901, ten feet of rock was shown in this quarry, and it is not known how much above the conglomerate its base is located. The bedding is not very regular, so that the rock for any considerable distance does not come out in layers of regular thickness. The quarry just described was also operated by Rose and Son.

In general, four or five feet higher than the Sharon conglomerate in the vicinity of Sharon occurs the Sharon coal, but that had been

[1]Warren folio (No. 172), Geol. Atlas U. S., U. S. Geol. Survey, 1910, library ed., p. 6, col. 1. Concerning the first use of the words Sharon, Garland and Olean for the names of geologic terranes, see Geol. Surv. Ohio, 4th ser., Bull. No. 7, pp. 13, 14.

[2]Foxburg-Clarion folio (No. 178), ibid., 1911, field ed., p. 36.

[3]Proc. Am. Assoc. Adv. Sci., Vol. XXX, 1882, p. 174.

[4]Top. and Geol. Surv. Pa., 1906–1908, 1908, p. 192.

[5]Bull. Geol. Soc. America, Vol. 20, 1910, p. 548.

mostly worked out on the hill under consideration. In the entrance to a drift of the Sharon coal at this vicinity a bank of blue argillaceous shale six feet or more in thickness, containing ferns in considerable abundance, was noted overlying the Sharon coal. This is evidently the Sharon plant shales which Professor White has described as the roof shales of the Sharon coal, stating that they "are often quite rich in fossil plants," a list of which he gave.[1]

Vernon Township—Across the State line in western Pennsylvania the rocks have been carefully described by Dr. I. C. White, and subdivided into a number of terranes, part of which are typically exposed in the western tier of townships. These divisions run across the State line into the eastern tier of townships in Ohio, where they may be readily recognized, while several of the formations extend westward for miles in Ohio, and several of the names have been used more or less frequently in the earlier portion of this bulletin. In these townships bordering Pennsylvania, the minor divisions to a great extent have been recognized, and it seems desirable to use them in the description of various sections which are to be found in these townships. The writer visited the type localities for most of these formations in western Pennsylvania and for the remaining portion, localities where they were typically shown according to the description in the county reports. For convenience in following the writer's descriptions of the sections in these townships, a condensed statement of Dr. I. C. White's classification of these formations, as shown in the bordering townships of western Pennsylvania, and found in the report for Erie and Crawford counties, will now be given. The Pottsville conglomerate is subdivided into the following members:

Homewood sandstone	
Mercer group	
Connoquenessing	Upper sandstone
	Quakertown beds
	Lower sandstone
Sharon	Upper iron shales
	Coal
	Lower shales
	Conglomerate[2]

The classification of the Subconglomerate formations (Mississippian) is given as follows:

[1]Second Geol. Surv. Pa., Q^3, pp. 52, 53.
[2]Ibid., Q^4, p. 55.

Group			Feet.
Shenango group		Shenango shale	50
		Shenango sandstone	25
Meadville group	Meadville	Meadville upper shale	25
		Meadville upper limestone	1
		Meadville lower shale	40
	Sharpsville	Sharpsville upper sandstone	50
		Meadville lower limestone	2
		Sharpsville lower sandstone	12
	Orangeville shale		75
Oil Lake group	Corry sandstone		20
	Cussewago	Upper shales	5
		Limestone	2
		Middle shales and flags	30
		Sandstone	25
	Riceville shales		80
Venango oil sand group	Upper sandstone (1st oil sand)		20
	Upper blue shales		100
	Middle sandstone (2d oil sand)		20
	Lower shales		140
	Lower sandstone (3d oil sand)		30[1]

Professor Schuchert's recent correlation of the Mississippian formations in the above list is as follows:

		East of Cincinnati axis, Ohio and Pennsylvania		
		Break		
Osagian	Pocono	Logan (Shenango shale of Pennsylvania)		
		Black Hand (Shenango of Pennsylvania)		
		Upper Cuyahoga (Meadville of Pennsylvania)		
Kinderhookian		Middle Cuyahoga (Sharpsville of Pennsylvania)		
		Lower Cuyahoga (Orangeville of Pennsylvania)		
		Sunbury		
		Berea (Cussewago and Corry of Pennsylvania)		
		Bedford	Bradfordian of Pa., and N. Y.	Knapp
				Oswayo
		Cleveland		Cattaraugus[2]

An interesting section was found in a small stream on the land of Emeline Sipes and Laura P. Brown, three miles north-northwest of Orangeville. The gully is crossed by the highway about one-fourth mile south of the four corners on the Orangeville road, which is one and one-fifth miles directly east of Vernon. The lower part of the run, beginning somewhat above the highway and extending to the level of Pymatuning Creek, is covered, but its upper portion exposes fair outcrops of the formations which will now be described.

[1]Ibid., see particularly pp. 66, 67, and the following pages up to 116 for the detailed description of the divisions.

[2]Bull. Geol. Soc. America, Vol. XX, 1910, p. 548.

Section on the Sipes and Brown Farms.

No.		Thickness. Feet.	Total thickness. Feet.
11.	The stream above the section is broadened out into simply a marsh; but loose blocks of Sharon sandstone are seen on the surface. The stream was followed for 10 feet higher than the last outcrop of rocks and there seemed to be no probability of any being exposed farther up	10	315
10.	*Shenango shales.* Thin-bedded, buff, flaggy sandstones in bed of stream. Five feet lower the sandstones are somewhat thicker and flaggy, fine-grained, and much like the Sharpsville in lithology. The top of this sandstone zone is 50 feet barometrically above the top of the Shenango sandstone. Lower part of the interval covered	20	305
9.	Thirty feet above the Shenango sandstone is a ledge of buff-colored, fairly fine-grained sandstone, with layers 6 inches or more in thickness. At this horizon there are several of these layers, making a ledge 3 or 4 feet thick. Lower are bluish shales alternating with coarse, arenaceous ones and thin sandstones. At the bottom are thinner bedded and finer grained, buff sandstones than those of the Shenango, which are shown in the bed of the run, but without the coarse-grained and rusty appearance of the Shenango sandstone, and therefore they are left in this zone	30	285
8.	*Shenango sandstone.* Massive, very coarse-grained sandstone, brownish-gray in color, with numerous brown or rusty spots, and in places containing numerous clay ironstone nodules. Six feet of this sandstone is shown in the fall at the site of the old grist mill, and 4 feet more is shown above in the stream. This massive ledge agrees fully with Read's description, where it is stated that the upper Berea sandstone could be taken out in any sized dimension blocks in Vernon Township, in the ledge to the east of Pymatuning Creek. He also stated that the rock would probably be injured by the iron balls in it so far as the color is concerned[1]	10	255
7.	*Meadville upper shale.* Three feet of blue, arenaceous shale shown in the fall just under the Shenango sandstone. This zone, however, is mostly covered	25	245
6.	*Upper Meadville limestone.* An impure calcareous layer, blue in color and very hard; but thickness not determined. The interval between this layer and the base of the Shenango sandstone agrees exactly in thickness with that given by Dr. White, between the base of the Shenango sandstone and upper Meadville limestone	--	--
5.	*Lower Meadville shales.* Upper portion of this interval mainly concealed. About 30 feet above its base are layers of arenaceous, buff shales to shaly sandstones. Lower part of the interval mostly concealed	50	220
4.	*Upper Sharpsville sandstone.* The layers of this sand-		

[1]Geol. Surv. Ohio, Vol. I, 1873, p. 505.

No.		Thickness. Feet.	Total thickness. Feet.
	stone are more or less flaggy, some of them from 8 to 10 inches in thickness	50	170
3.	A somewhat calcareous, sandy layer, thickness not determined, which probably represents the horizon of the lower Meadville limestone, since its distance below the top of the sandstone agrees with the thickness of the corresponding interval in Dr. White's section	--	--
2.	*Lower Sharpsville sandstone.* Consisting of layers of flaggy, buff sandstone	15	120
1.	Concealed to the level of Pymatuning Creek	105	105

No indication of the Berea was found in this locality. The conglomerate layer of the Sharon shown at the base of the Troutman quarry about one mile south of this run was barometrically only five feet higher than the highest sandstone seen in the above section. The old quarry in the field northwest of the Troutman quarry and 55 feet lower than its base shows a two-foot ledge of buff, coarse-grained Shenango sandstone containing iron nodules.

The above section is an interesting and valuable one, since it gives a very fair idea of the character of the rocks from the base of the Sharpsville sandstone nearly to that of the Sharon conglomerate; in fact, if the top of the section be carried about a mile to the south to the Troutman farm, then 27 feet of the Sharon conglomerate may be added to it. The stream gives a complete section of the Shenango sandstone with an accurate idea of its character, and also a very fair one of the Sharpsville sandstones. It is also thought that the horizon of both Meadville limestones is shown, although the lower one is rather impure and not typical, but the thickness of the intervals above and below each one corresponds very closely with that given by Dr. White in his "Generalized Section" of these formations in western Pennsylvania.[1]

Mr. M. C. Read wrote the reports for the Ohio Survey on Trumbull and Ashtabula counties and prepared the geological map for them. The outcrop of the Berea grit on the map of these two counties is indicated by a green line in the midst of the yellow area which represents the "Waverly group" and, near the State line in Vernon and Kinsman townships, the green line is divided.[2] In his description of Trumbull County under the heading of Bedford shale, Mr. Read stated that "in Kinsman and extending into Williamsfield, Ashtabula county, these shales [Bedford] belonging below the Berea, are in fact interposed between two members of the latter. The Berea in Mesopotamia, is separated into two parts by about two feet of shale. On the eastern margin of the county, the upper part of the Berea passes

[1]Second Geol. Surv., Pa., Q^4, p. 66.
[2]See Geological Map of Ashtabula, Lake, Geauga and Trumbull counties, opposite p. 483, Vol. I, Geol. Surv. Ohio.

out of the state near the north [south]-east corner of Kinsman, the lower member passing along the higher ground, east of the Pymatuning, follows the course marked by the northern green line on the map, leaving the state somewhere near the northern part of Williamsfield, but is there covered with drift."[1] Again in describing the Berea grit he wrote that "in Vernon, on the west side of the ridge, east of Pymatuning creek, it is exposed in massive layers, from which blocks of any desired dimensions may be taken. It is here firm and strong, but contains nodules of iron ore which will be likely to color the stone and detract from its value if used for building purposes."[2] The description for this part of Read's Berea evidently agrees with the division called the Shenango sandstone in the above section. Read also stated under his description of "The Conglomerate" in Trumbull County that the horizon of the Berea grit "is about 100 feet below the conglomerate."[3]

So far as the writer is aware, Dr. I. C. White first reported that the upper Berea sandstone of Read did not belong in the Berea at all and he correlated it with his Shenango sandstone. A foot note by Dr. White under the heading of "The Shenango Sandstone" in his original description contains the following statement: "This is Mr. M. C. Read's *Upper* Berea, Geol. Ohio, Vol. I, page 508. But it evidently has nothing to do with the Berea Grit proper."[4] The following year Dr. White published a more detailed account of his opinions concerning the classification of the rocks in Vernon Township, and correlated Read's lower member of the Berea grit with his Sharpsville sandstone. Dr. White wrote as follows under the heading of Sharpsville Sandstone: "After my study of the persistency of the bed of limestone [Meadville lower limestone] which lies in the body of the sands, I distinguished those above and below as *Upper and Lower*(*Sharpsville*) *sandstones*. But apart from the limestone they form together but one deposit of sand, which I traced in 1876 along the Shenango and Pymatuning creeks into Vernon township, Trumbull county, Ohio. Here I found it called by Mr. Read *Lower Berea*; my *Shenango Sandstone* above it being called *Upper Berea*. But the original *Berea Grit* of Medina, Lorain, Ashland and Richland counties of Ohio, under the *Cuyahoga shale formation* of Ohio, lies from 270′ to 300′ beneath the *Ohio Conglomerate*; whereas this *Sharpsville Sandstone* ('Lower Berea') lies only 145′ beneath the *Sharon* (*Ohio*) *Conglomerate*, and we must look 100′ lower for the genuine Berea, viz: in the *Corry and Cussewago* sandstones of the Oil Lake group (the *Pithole grit* of the Oil regions)."[5] Dr. White also gave the following section, which he stated was made in Vernon Township, three miles north of Orangeville, and it appears probable

[1]Ibid., p. 508.
[2]Ibid., p. 505.
[3]Ibid., p. 502.
[4]Second Geol. Surv. Pa., Q^3, 1880, p. 60.
[5]Ibid., Q^4, pp. 85, 86.

that it was obtained at the same locality as the one which is described above from Sipes Run:

"Sharon (Ohio) Conglomerate, very pebbly.*		25′
Shenango,	Shale	50′
	Sandstone, (Read's *Berea Upper S.*)†	15′
Meadville shales,		80′
Sharpsville sandstone, (Read's *Berea Lower S.*)‡		60′
Concealed to the level of the Pymatuning creek		110′"[1]

In the above section it will be noticed that Dr. White gives the thickness of the Shenango sandstone as 15 feet, while in the writer's it is listed as only 10 feet. It is quite possible, however, that some of the thinner layers of finer grained sandstone shown in the run above what was called the top of the Shenango sandstone might be included in it.

Later, Prof. H. P. Cushing reached a conclusion similar to that of Dr. White concerning the correlation of these sandstones, but his opinion was based upon the study of the Berea grit in its typical region and acquaintanceship with the formations of northeastern Ohio. This will be seen from the following account of the correlation of these sandstones published by Professor Cushing: "In the Waverly Group, throughout the larger part of northern Ohio, there is one strong persistent sandstone horizon, and but one, the Berea Grit. In tracing its outcrop to the east, Mr. Read, when near the state line, came upon three sandstones near this horizon all resembling some lithological phases of the Berea. He concludes that the Berea here has split into two parts, or possibly even into three. The dark blue or black shales with black slate fauna, which he found lying between his two lowest sandstone members, he called Bedford shales, thus putting part of his Berea below the Bedford. This same shale which he calls Bedford in Kinsman township, he makes do duty as Cuyahoga shale—Berea shale of Prof. Orton — in Vernon township and at Warren. In my section near Warren the lower two of these three sandstones appear. The upper one of the two is the stone quarried near Warren and, according to the Ohio Reports, lies in the Cuyahoga shale. It is here considerably thinner than on the state line; directly under it the black Berea shale appears. This stone is *beyond doubt* the equivalent of the middle sandstone near the state line, that is as certainly the equivalent of the Sharpsville sandstone of Prof. White in Crawford County, Pa. North of Warren another sandstone appears directly under the black shale and is the equivalent of the lowest sandstone on the state

"*The *Sharon coal* overlies the Conglomerate close by.

†Upper green line on Reed's [Read's] map of Trumbull county.

‡Lower green line on the same. This out-crop of the rock I traced continuously from Sharon, where it rises from the water, up the Shenango and Pymatuning valleys, by two lines, to the same point in the northern line of Trumbull county, Ohio."

[1] Ibid., p. 86.

line, of the Corry sandstone of Prof. White in Pa., of the Berea of Northern Ohio."[1]

Professor Cushing also gave the following section for "Ashtabula and Trumbull Counties, Ohio, near Pa. line":

"Conglomerate

Unexposed	40′	235′
Shenango sandstone	15′	
Cuyahoga shales and flags	90′	
Warren sandstone	50′	
Berea shale	40′	
Berea grit	35′	
Bedford shales	15′"[2]	

In the above section Professor Cushing used the term Berea shale of Meek in the sense in which it had been used by Dr. Orton in the Ohio reports, as has been explained in an earlier part of this bulletin, and for which the writer has used the name Orangeville shale or formation. The name Warren sandstone was used as stated by Professor Cushing for the sandstones quarried near that city, several quarries of which are described in this bulletin under the heading of "Sections Near Warren," (p. 645) and which he states "is *beyond doubt* the equivalent of the middle sandstone near the state line, that is as certainly the equivalent of the Sharpsville sandstone of Prof. White in Crawford County, Pa." Finally, on Professor Cushing's section it will be seen that the upper sandstone is called the Shenango, the top of which is given as 40 feet below the conglomerate. The order of this section will be found in entire agreement with the sections which were made by the writer in these townships with some variation in the thickness of the several intervals as is to be expected in the case of two observers working separately and not always in the same localities.

In Mr. Read's report on Trumbull County, under the heading of Cuyahoga shale, he briefly described the fossiliferous shale on the Mahoning River, west of Warren, which has been more fully described in this bulletin (p. 647), and also at another locality near the western line of Vernon Township, where he stated that "layers of the shale are filled with a profusion of *Lingulæ* and a great variety of chambered shells, but the material containing them is so soft and friable that they cannot be well preserved. In the bed of the same stream, at a little lower level, beau-

[1]Proc. Am. Assoc. Adv. Sci., Vol. XXXVI, 1888, p. 215.
[2]Ibid., p. 214, section No. 2.

tifully preserved *Discinæ* are so abundant that slabs of a large size may be obtained, completely covered by them."[1]

Professor Cushing prepared a detailed paper on a "Geological section through Ashtabula and Trumbull Counties, Ohio," of which the section in the Proceedings of the American Association for the Advancement of Science is but the bare outline, and the complete paper has never been published. Professor Cushing has kindly put this manuscript in the writer's hands with the statement that he may make whatever use of it he pleases; but when engaged in field work in these counties it was unknown to the writer, and came into his possession after most of this bulletin was written, so that he has been unable to quote freely from it as he would have done if it had been sent him at an earlier date. In this manuscript Professor Cushing refers to the shale locality described by Read in the western part of Vernon Township as well as the one near Warren, only using the term Berea shale instead of Cuyahoga under which they were described by Read. Professor Cushing's description is as follows: "In his report [Read's] he mentions the occurrence of Berea shale in two localities in Trumbull county, viz., in the bed of the Mahoning west of Warren, and near the west line of Vernon (Geol. Surv. O., Vol. 1, p. 504). It occurs in each place as he states, is covered in each by the Sharpsville sandstone, and in the latter locality the Berea is found underlying it. *This is the same formation that he calls Bedford shale near the state line* (p. 508). A continuous line of sections through Warren, Bazetta, Johnston, Vernon, Kinsman and Williamsfield townships at this horizon shows always the threefold division of sandstone below with a black, pyritiferous layer at its top, followed by a blue-black shale with a Lingula fauna, and then by a series of flags. I followed this shale to Orangeville, Prof. White's typical locality for his Orangeville shale, and proved their identity. Nowhere does it at all resemble the Bedford shale, either lithologically or paleontologically. By wrongly identifying it with the Bedford shale in Kinsman township, and then considering the sandstone above it as Berea, losing sight of its identity with the flagstone at Warren, Mr. Read's measurement of the interval between the Conglomerate and the Berea was made too small by 100 feet."

The high ground to the east of Pymatuning Creek in Vernon, Kinsman, Williamsfield and Andover townships as well as the bordering townships across the State line in Pennsylvania, were examined with some care for outcrops and sections which might be of assistance in describing the stratigraphy of this region. In this investigation most of the streams of any size were followed and also a considerable number of the roads were traversed. Some of the rather isolated observations in connection with this work are perhaps worth recording for the benefit of future students of this region. The hill east of Vernon

[1]Geol. Surv.Ohio, Vol. I, p. 504.

is fairly steep and in a mile rises some 260 feet. The highway leading directly east from Vernon, which is the first one north of the Sipes and Brown section, climbs this hill and crosses the highest part of the divide which is near the Ohio-Pennsylvania line. The highest land near the State line at this locality, according to the topographic sheet, is about 275 feet higher than the four corners on the Orangeville-Kinsman highway directly east of Vernon. The barometer gave this interval as 280 feet, to which at least 55 feet is to be added to bring it down to the creek bottom, making a total rise of some 340 feet in a distance of 1.8 miles. After crossing this hill a ledge of the Sharon conglomerate was found on the first north and south road in Pennsylvania, about one-fourth mile north of the three corners. There is a ledge of the conglomerate in the run at this locality, 3 to 4 feet in thickness, which is 55 feet lower than the high ground near the State line. This locality is near the middle of the western line of West Salem Township, Mercer County, Pennsylvania.

Rather more than a mile to the north of the outcrop just noted is another one of the Sharon conglomerate just east of the cemetery on the Foulk farm. It is a massive, very coarse-grained quartz sandstone, brownish to bluish-gray in color. The individual grains of quartz sand are white. The ledge as shown in the quarry is about 14 feet thick. Some of the bedding is rather irregular, so that the thickness of the layers cannot be expected to run evenly for any considerable distance. The top of the hill in the cemetery is some 20 feet higher than the conglomerate ledge.

At the three corners about one-half mile north of the cemetery the writer turned west and crossed the State line into Ohio. North of this east and west road and the Otis Marsh house, in the northeastern corner of Vernon Township, is a ledge of Sharon conglomerate which is 25 feet lower than the outcrop in the cemetery on the Foulk farm. A little to the northwest of the Marsh outcrop is an old quarry in the conglomerate. To the west of the Marsh farm is Spring Run, a tributary of Mill Creek, and along part of its course are outcrops of the Waverly rocks. The following section was obtained on this run:

Section on Spring Run.

No.		Thickness. Feet.	Total thickness. Feet.
10.	*Sharon conglome ate.* On Otis Marsh farm.		
9.	Covered interval, some 93 feet barometrically	93	261
8.	*Meadville upper limestone* (?). An impure calcareous layer, which probably is the western continuation of this stratum. Just below the limestone are slightly calcareous layers which contain abundant and well preserved fossils. At the base a layer of flaggy sandstone, containing specimens of Pelecypods and some other fossils	2±	168

No.		Thickness. Feet.	Total thickness. Feet.
7.	Bank of 15 feet of bluish shale with thin layers of sandstone and some nodular, concretionary layers. Part of the shale weathers to a rather olive color. This is the first shale bank above the highway	15	166
6.	Partly covered interval with buff to bluish-gray, fine-grained, flaggy sandstone	25	151
5.	More or less covered interval	40	126+
4.	*Meadville lower limestone.* Impure, glassy, blue limestone, 1 foot 4 inches thick; above which are three feet of bluish shales, while thin sandstones are below the limestone stratum	$1\frac{1}{3}$	$86\frac{1}{3}$
3.	Mainly covered interval	45	85
2.	Bluish, argillaceous shale, about 3 feet shown in bank of run	3	40
1.	Covered interval as far as Spring Run was followed down stream	37	37

In the above section if the upper impure limestone is the equivalent of the upper Meadville, then it occurs about 93 feet below the ledge of Sharon conglomerate on the Marsh farm, which may not be its actual base. The interval between the Meadville lower limestone and the same conglomerate ledge is 175 feet, and the interval between the two limestones is about 81 feet. On returning, however, readings taken only 20 minutes apart at the two limestones gave the thickness of the interval between them as 95 feet. In the main the thickness of the above intervals was obtained by the barometer. The difference, however, in their thickness is not great when compared with Dr. White's standard section for Crawford and Erie counties, since that gives 100 feet from the base of the Sharon conglomerate to the Meadville upper limestone; 191 feet from the Sharon to the Meadville lower limestone, and 90 feet for the thickness of the interval between the Meadville lower and upper limestones.[1] No outcrops of the Shenango sandstone were found in this northeastern part of Vernon Township, and the adjacent part of West Salem Township in Pennsylvania.

In Professor Cushing's manuscript, which was written more than twenty years ago, is the following description of a section in Vernon Township, which perhaps the writer did not visit:

"The best section was obtained at Andrew Biggen and L. P. Langley's places in the northern part of the township on the road from Kinsman to Burghill. In the creek on Mr. Langley's place, near the road, the Sharpsville sandstone is well exposed, with a thickness of 50 feet, and presenting the same characters as in Williamsfield. (Two and one-half miles from Kinsman, on the road to Greenville, Pa., I obtained specimens of *Lingula cuyahoga* from shaly partings in this sandstone.) Above it lie 80 feet of intermingled soft blue-gray clay shales, thin

[1]Second Geol. Surv. Pa., Q^4, p. 66.

bedded friable yellow sandstones, buff colored micaceous sandy shales and flags, and hard, ferruginous and slightly calcareous flags. The relative amounts of these vary much in different sections; sometimes the flags fill nearly the entire interval, sometimes no more than half. In the upper 20 feet poorly preserved fossils are quite abundant in the sandy layers. * * * * Directly above lies the Meadville upper limestone, which is here 6 inches thick, and unfossiliferous * * *

"The Shenango sandstone lies 10 feet above this limestone. The intervening shales are not well exposed, seem to consist in the main of soft gray shales, and are unfossiliferous so far as I could discover. The sandstone is an almost purely siliceous grit, firmly cemented, stained very yellow with iron, contains numerous clay iron nodules of all shapes and sizes, and badly preserved plant and fish remains. In general it is very massive, but sometimes becomes thin bedded, when it is finer grained, less purely siliceous, and contains flat nodules of clay or shale."

The road from Vernon to Johnstonville crosses Mill Creek about one mile west of Vernon. Outcrops of sandstone occur on this creek and another stream which is crossed before reaching the first north and south road west of Vernon. The writer did not have time to examine them; but judging from the topographic sheet and the section studied on Sugar Creek, two miles to the northwest, they are stratigraphically higher than the Berea sandstone.

On the southern bank of Sugar Creek below Corinth, just over the township line in Johnston Township, is a bank of black shale capped by a thin-bedded to shaly sandstone. The following section was measured near the lower end of the bank at this locality:

Corinth Section on Sugar Creek.

No.		Thickness. Feet.	Total thickness. Feet.
3.	Blackish, argillaceous shale, about $1\frac{1}{2}$ feet shown	$1\frac{1}{2}$	$12\frac{1}{6}$
2.	Gray, shaly to thin-bedded sandstone. This same zone is apparently shown in highway cuttings on both roads crossing the creek a little below this section	$1\frac{1}{6}$	$10\frac{2}{3}$
1.	Black, tough, rather massive shale before weathering, which splits up in rather large blocks. Fossils common in the lower part near creek level	$9\frac{1}{2}$	$9\frac{1}{2}$

Some distance below Corinth on Sugar Creek, sandstones were seen which are in the Berea formation. The Corinth section is in the Orangeville formation; but time did not permit determining whether zone No. 1 corresponds to the Sunbury shale and zone No. 2 to the Aurora sandstone (?) or whether it is stratigraphically higher in the formation.

This is the locality described as follows by Mr. Read under the heading of "The Cuyahoga shale":

"Near the west line of Vernon, layers of the shale are filled with a profusion of *Lingulæ* and a great variety of chambered shells, but the material containing them is so soft and friable that they cannot be well preserved. In the bed of the same stream, at a little lower level, beautifully preserved *Discinæ* are so abundant that slabs of a large size may be obtained, completely covered by them."[1]

This section was also studied by Professor Cushing, who wrote as follows concerning it: "In his report [Read's] he mentions the occurrence of Berea shale in two localities in Trumbull county, viz., in the bed of the Mahoning west of Warren, and near the west line of Vernon (Geol. Surv. Ohio, Vol. I, p. 504). It occurs in each place as he states, is covered in each by the Sharpsville sandstone, and in the latter locality the Berea is found underlying it. *This is the same formation that he calls Bedford shale near the state line* (p. 508)."

Kinsman Township.—This township lies directly north of Vernon and is crossed from the southeast to the northwest by the fairly steep escarpment east of Pymatuning Creek. From this high ground to the east a number of streams descend to the Pymatuning, some of which give fairly good outcrops of the rocks passed over. Probably the best one for this purpose is Mill Creek, that rises in West Salem Township, Pennsylvania, and flows across the southeastern part of Kinsman Township not far north of the township line, which it finally crosses into Vernon Township before receiving Spring Run, and farther to the southwest enters Pymatuning Creek. The stream was followed from the lowest Paleozoic outcrops shown on it, which are referred to the Berea formation, to the State line, where the Shenango shales occur. At this locality is the fourth bridge as the stream is ascended, six miles north of Orangeville, four and one-half miles southeast of Kinsman and six miles northwest of Greenville, Pennsylvania. At this corner the farm of J. A. McBroom is just over the State line in West Salem Township.

Mill Creek Section.

No.		Thickness. Feet.	Total thickness. Feet.
21.	*Sharon conglomerate.* Top of Hobart Hill (on the A. C. Hobart farm), one-half mile west of State line, and the northeast corner farm of Vernon Township. There is an old quarry at this locality in which part of the rock is rather pebbly, while other portions consist of a very pure quartz sandstone, light gray to white in color. Mr. D. D. F. Hobart stated that about 1884 a well was drilled at this locality, which gave 15 to 20 feet of		

[1]Geol. Surv. Ohio, Vol. I, p. 504.

No.		Thickness. Feet.	Total thickness. Feet.
	Sharon conglomerate, from which the thickness used in this section was taken. The top of the ledge is glaciated, showing glacial striæ which run about N. 5° E. and S. 5° W	15±	331
20.	Covered interval down the northern slope of Hobart Hill to Mill Creek	36±	316
19.	*Shenango shales.* Shales on bank of creek at fourth bridge in going up stream, 6 miles north of Orangeville. Lower, the zone is partly covered; but also showing shales alternating with thin layers of sandstone	10	280
18.	*Shenango sandstone.* At top, finer grained, buff sandstone in bed of creek. At base, in bank of creek, a ledge of very coarse-grained, brownish sandstone, which lithologically resembles the Shenango. A little above the ledge is an old pit, where a rather massive sandstone, containing clay ironstone nodules, has been quarried to a slight extent. This ledge is on the farm of William Wade, the southeastern corner farm of Kinsman Township	10	270
17.	Mostly covered interval; but at the base in the bed of the creek is a somewhat calcareous layer, which is at the third bridge, apparently on a lane leading to a farm house	20	260
16.	Mostly covered interval; but at the base, in the bed of the creek, a blue, somewhat calcareous layer	10	240
15.	Partly covered interval; but near the base the Meadville upper limestone is shown. On the second road on each side of the creek is a ledge of fine-grained, buff sandstone, containing calcareo-iron concretions	14	230
14.	*Meadville upper limestone* (?). Two feet below the sandstone ledge, as shown on the highway, is a layer of calcareous, bluish rock, which to some extent resembles lithologically the Meadville upper limestone. This outcrop is on the north and south highway, north of Mr. Hobart's house. This zone of blue, calcareous shale is also shown in the creek bed above the highway.	1±	216
13.	Partly covered zone; but ledges of bluish-gray to buff, fine-grained sandstone shown in bed of creek beneath bridge	25	215
12.	Buff to bluish, fine-grained, flaggy sandstones, alternating with shales. The top of the fairly heavy flags is 20 feet higher than the base of the zone. Near the base of the sandstone a layer containing numerous specimens of *Orbiculoidea newberryi* (Hall) Herrick, where slabs containing good specimens may be obtained. A specimen showing the internal characters of the pedicle valve and the pedicle area was compared with the hypotype of this species from Cuyahoga Falls, Ohio, in the New York State Museum (which is shown on fig. 18, pl. 4 F, pt. 1, Vol. VIII, Pal. N. Y.), with which it closely agrees. The pedicle area is better		

No.		Thickness. Feet.	Total thickness. Feet.
	preserved on the Mill Creek specimen than on the hypotype	20	190
11.	Shale zone composed of bluish, argillaceous shales, containing numerous calcareo-iron concretions	$3\frac{1}{2}$	170
10.	*Sharpsville upper sandstone.* Flaggy, irregular layers of sandstone along the bed of the creek. At the base of this zone a rather massive sandstone layer	$26\frac{1}{2}$	$166\frac{1}{2}$
9.	At the top, rather thin shales; but most of the zone composed of fairly flaggy, sandstone layers, about like the overlying zone	20	140
8.	*Meadville lower limestone.* Blue, compact, impure limestone, rounded on the weathered edges, with the lithologic appearance of this limestone in its typical region. The glassy lustre is noticeable on the fresh fracture of an unweathered surface. Thickness 9 inches. Exposed on the creek bank, just below the house of Mr. W. Bidwell, near the Kinsman-Vernon Township line. This locality is about three-fourths of a mile down the stream from the bridge where the Meadville upper limestone(?) is exposed; more than a mile above the Orangeville road bridge over the creek, and nearly $2\frac{1}{2}$ miles southeast of Kinsman	$\frac{3}{4}$	120—
7.	*Sharpsville lower sandstone.* Fairly massive, compact, fine-grained, bluish to buff sandstones. An old quarry on the Leonard Cole farm, just south of the creek, is some 6 miles northwest of Orangeville. The Meadville lower limestone is apparently shown just at the top of the old quarry wall. The thicker layers of sandstone in the quarry are light gray in color, fine-grained, making a rather compact rock, which in some layers crumbles rather readily in the fingers. There are many layers of shaly sandstone to shale, and the thickest sandstones do not apparently split into very even layers. Sixteen feet was measured in the quarry wall	19	119
6.	*Orangeville formation.* Partly covered on eastern bank of creek below the base of the quarry; but in the western bank $14\frac{1}{2}$ feet is shown, of blue, arenaceous and argillaceous shales, alternating with mostly thin-bedded sandstones. In the creek, below the quarry, is an occasional layer of bluish, thin-bedded sandstone with ripple-marks. On the bank of the creek, below the quarry, and at the base of the cliff on the opposite side, is a layer of blue, argillaceous shale, which contains numerous specimens of a large *Lingula*, an *Orbiculoidea* and a few other fossils	$14\frac{1}{2}$	100
5.	Upper part of zone covered; but some rods below the quarry is bluish, somewhat gritty shale, containing large numbers of *Lingula melie* Hall, a large *Lingula* and *Orbiculoidea*. Below these shales, in bank and bed of the creek, are thin, bluish, fine-grained flaggy sand-		

No.		Thickness. Feet.	Total thickness. Feet.
	stones, alternating with bluish, argillaceous and arenaceous shales	$15\frac{1}{2}$	$85\frac{1}{2}$
4.	Upper part of zone covered; but at the base $2\frac{1}{2}$ feet of bluish, argillaceous shale, some of which is gritty, which on the weathered surface is of brownish color	10	70
3.	Partly covered zone; but exposed rocks all decidedly blue shale	20	60
2.	*Berea grit.* Ledge of coarse-grained sandstone forming bed of stream, containing much iron pyrites, and the upper surface rough and irregular, with all the appearance of the top of the Berea. About one foot of the massive sandstone is shown in each stream, Mill Creek and the branch from the southeast, (Spring Run ?). Below the massive sandstone is shown another foot of blackish, gritty, shaly rock, containing iron pyrites	2±	40
1.	Followed the stream to a point 40 feet lower than the Berea grit; but the lower 35 feet was all in gravel banks. In sight of the Orangeville-Kinsman highway	38	38

From the shales of No. 6 of the above section, as exposed along Mill Creek on the Leonard Cole farm, which form the upper zone of the Orangeville formation, the following species were collected:

1. Lingula cuyahoga Hall (?) (a)

The most of these specimens have about the size, outline and proportion of length to width (5 to 3) of this species. They are, however, somewhat smaller than the type specimen of this species in the American Museum, and the proportion of some specimens is nearer 3 to 2; but they are larger than the types of *L. melie* Hall, as is shown by the following table:

	Length.	Width.
Mill Creek specimen,	14.5 mm.	10 mm.
" " "	14.5 "	8.75 "
" " "	14 "	9.5 "
" " "	13.5 "	8.5 "
" " "	13 "	9 "
Type specimen,	15 "	10 "

Again, these specimens resemble more closely Herrick's figures of *L. atra* (Geol. Surv. Ohio, Vol. VII, pt. 2, pl. 22, figs. 5 and 6) than his figure 9 of *L. cuyahoga*. The measurement of his figures is as follows:

	Length.	Width.
L. atra, fig. 5,	14.7 mm.	9.8 mm.
" " " 6,	15.8 "	10.4 "
" " Herrick's description,	16 "	10.5 "
L. cuyahoga, fig. 9,	12.9 "	7 "

It will be seen that the size of fig. 5 of *L. atra* is almost identical with that of the first specimen in the Mill Creek list. An examination of the types of *L. melie* and *L. cuyahoga* in the American Museum led the writer to think that perhaps Herrick's fig. 9, which he called *L. cuyahoga,* ought to be referred to *L. melie,* and that figs. 5 and 6 of *L. atra* may perhaps be referred to *L. cuyahoga.* The originals of Herrick's figures have not yet been examined, which is necessary before a positive opinion can be given concerning these very similar forms.

2. Lingula melie Hall -- (r)

A few specimens, which are of medium size as compared with authentic ones of this species from the typical locality, and have about the same proportion of length to breadth, viz., 3 to 2. The measurement of 3 specimens is as follows:

	Length.	Width.
Mill Creek specimen,	9 mm.	6 mm.
" " "	7.5 "	5 "
" " "	7 "	4.75 "
Type specimen, fig. 3,	11 "	7.2 "
" " " 4	9.5 "	5.5 "

It will be seen that the first two of the above Mill Creek specimens have the exact proportion of 3 to 2 for length to width, while that of the third is nearly the same; but that in actual size they are somewhat smaller than the type specimens of this species in the American Museum.

3. Orbiculoidea herzeri Hall and Clarke ------------------------- (r)

The specimens have the narrower pedicle area of this species rather than the broader one of *O. newberryi* (Hall) Herrick, as stated in foot note on p. 126, pt. 1, Vol. VIII, Pal. N. Y. The interior of a pedicle valve and its impression were compared with type specimens in the New York State Museum, with which they agree. The apex of a brachial valve, which probably belongs to this species, is rather high, being about 11.5 mm. long and 12 mm. wide.

4. Nucula houghtoni Stevens ------------------------------------ (rr)

These specimens are not quite so long as those described by Hall, and the concentric varices of growth are stronger toward the margin than in his figures; still they are considered as identical Length of Mill Creek specimen 12.5 mm., and height 10.5 mm.; while Hall's description gives the length as 17 mm. and height as 13 mm., in which the length is more than one-fourth greater than the height, while in the specimens under consideration it is a little less.

5. (?) Schizodus cf. cuneus Hall --------------------------------- (rr)

The specimen agrees with Herrick's fig. 15, pl. 5, Vol. III, Bull. Sci. Lab. Denison University, which he called *Schizodus cuneus.* This specimen and Herrick's figure

do not agree closely with the figures accompanying Hall's description of the species, and it is a question whether they are identical. The Mill Creek specimen is marked by close, thread-like, concentric lines and it may possibly be a *Nucula*.

6. (?) Sanguinolites sp .... (rr)
An external impression which is not well preserved.

This section along Mill Creek is one of the most important found in eastern Trumbull and Ashtabula counties, since it gives fairly good outcrops of the formations from the top of the Berea grit to the Sharon conglomerate. There are few continuous sections in northeastern Ohio as long as this one, and although most of the measurements are barometric, they were checked by two readings, so it is thought that they are fairly accurate. Perhaps the most important fact shown by this section is that the interval from the Berea grit up to the Sharon conglomerate is in the neighborhood of 276 feet. This, of course, shows conclusively that Read was mistaken in stating that in Trumbull County the horizon of the Berea grit "is about 100 feet below the Conglomerate."[1] This determination is in close agreement with that of Dr. I. C. White, who stated that the "*Cuyahoga shale series* * * * shows a constant thickness of about 300′ all over northern Ohio and northwestern Pennsylvania;"[2] although he was mistaken in supposing that this thickness remained constant over all of northern Ohio. Professor Cushing made the interval between the Berea and the conglomerate 235 feet in his section in Ashtabula and Trumbull counties, near the State line,[3] which is 40 feet less than the estimate in the writer's section of Mill Creek. In this section there is about 60 feet of the Orangeville formation, the lower 25 feet of which is blue shale; but in the upper part are sandstones alternating with shales. The Sharpsville lower sandstone is some 19 feet in thickness above which is the Meadville lower limestone, 9 inches thick and resembling closely in lithologic appearance this limestone in its typical region. From the Berea sandstone to the Meadville lower limestone is 79 feet in this section, and 87 feet in Professor White's generalized section for Erie and Crawford counties[4] from the Meadville lower limestone down to the Corry sandstone, the latter of which he regarded as the eastern continuation of the Berea grit.[5] In the Mill Creek section there is some 46½ feet, mainly sandstones, which may be called the Sharpsville upper sandstone, which is given a thickness of 50 feet on Dr. White's generalized section. On the Mill Creek section the interval from the Berea grit to the horizon that has been tentatively correlated with the Meadville upper limestone is 175 feet, or according to another record, with

[1]Geol. Surv. Ohio, Vol. I, p. 502.
[2]Second Geol. Surv. Pa., Q^4, 1881, p. 86.
[3]Proc. Am. Assoc. Adv. Sci., Vol. XXXVI, 1888, p. 214, No. 2 of sections.
[4]Second Geol. Surv. Pa., Q^4, p. 66.
[5]Ibid., p. 94.

an interval of nearly one hour between the readings, 180 feet, while on Dr. White's generalized section the thickness for the same interval is 179 feet. The intervals between the two Meadville limestones is 95 feet on Mill Creek and 90 feet on Dr. White's section. The interval from the Meadville upper limestone to the Shenango sandstone on Mill Creek is 44 feet, as compared with 25 feet on Dr. White's section, and the Shenango sandstone 10 feet thick against 25 feet in the Pennsylvania section. From the Shenango sandstone in Mill Creek to the Sharon conglomerate on Hobart Hill is some 46 feet, and 50 feet in Dr. White's section. Finally, from the Meadville upper limestone on Mill Creek to the Sharon conglomerate on Hobart Hill is 100 feet, or 105 feet, according to another reading, while the same interval on Dr. White's section is also 100 feet.

Mr. Hobart stated that in 1884 or thereabouts a well was drilled on the Hobart Hill in prospecting for coal, which began on the high ground. According to his recollection it passed through 15 to 20 feet of Sharon conglomerate, and at a depth of from 60 to 70 feet a sandstone was struck, which would indicate from 45 to 50 feet for the thickness of the Shenango shales, when a sandstone perhaps 15 feet in thickness was reached, which is apparently the Shenango.

Below this sandstone was shale to the bottom of the well which was 90 feet deep. The Hobart Hill is on the first farm to the north of the Otis Marsh farm, where the Sharon conglomerate has already been reported.

Other outcrops of the Shenango sandstone were not seen in the southeastern corner of Kinsman Township, aside from the one already described on Mill Creek, but interesting outcrops of it were found on the James Brockway farm in the northwestern part of West Salem Township, Mercer County, Pennsylvania. This locality is just east of a four corners on the Kinsman-Greenville highway, five miles east of Kinsman. There is an old quarry at this locality just south of the Kinsman-Greenville road where 10½ feet of the sandstone is shown. It is a coarse-grained, quartz sandstone, containing numerous clay ironstone pebbles. The general color of the stone is buff with numerous rusty spots, due to iron staining, but the individual grains of quartz sand are white as seen through a microscope. In a run below the James Brockway quarry is an outcrop of the Meadville upper limestone less than a foot in thickness, above which about 10 feet of the Meadville upper shale is shown. This section is as follows:

Section on James Brockway Farm.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Shenango sandstone.* Coarse-grained, quartz sandstone, containing numerous clay ironstone concretions. Buff color in general, with numerous rusty spots; but indi-		

No.		Thickness. Feet.	Total thickness. Feet.
	vidual quartz grains are white. The rock has the lithologic characters of the Shenango sandstone as exposed about Jamestown, Pennsylvania, where it was identified and described by Dr. White, who named this terrane	$10\frac{1}{2}+$	56
3.	Covered interval	$34\frac{1}{2}$	$45\frac{1}{2}$
2.	*Meadville upper shales.* Shales and shaly sandstones exposed on bank of run	10±	11
1.	*Meadville upper limestone.* Exposed in run below the Brockway quarry and is less than a foot in thickness	1 −	1 −

To the east of the highway and the quarry described above is a newer one, in which about 6 feet of the Shenango sandstone is exposed. It is a buff, massive sandstone containing numerous iron-stone concretions. The top of the rock is glaciated with striæ running N. W. and S. E. A hill directly south of the Brockway quarry is 55 feet higher than it, and probably is underlain by the Sharon conglomerate, since on Dr. White's generalized section the thickness of the Shenango shales, which fill the interval between the Shenango sandstone and the Sharon conglomerate, is 50 feet,[1] and again the massive Sharon conglomerate resists erosion and would serve as a support for the hill. On the highway to the southwest of the Brockway quarry, and 35 feet higher than it, are shaly micaceous sandstones, which probably belong in the flaggy layers at the base of the Sharon conglomerate.

An interesting section of the upper part of the Berea formation is shown on Stratton Creek, beginning about one and one-half miles above and to the northeast of Kinsman. The lowest outcrops occur on the eastern bank of the creek a little below the highway bridge at the old Hamilton mill, which is now the Kinsman Electric Light Plant. These lowest outcrops consist of rather thin-bedded, fine-grained sandstones, bluish in color, alternating with blue shales. Farther down the creek the banks are apparently soil and gravel, while for one-fourth mile above the mill up to the pond the older rocks are frequently shown, although there are not infrequent banks of drift. The following section, which is an interesting one, was measured along this part of the stream.

Section on Stratton Creek.

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Orangeville formation.* Blackish, fissile shale. This outcrop is on the western bank, opposite the dam, which rests on top of the Berea sandstone	5±	$36\frac{2}{3}$
4.	Zone of shaly, light gray sandstone, composed of fine quartz grains, alternating with blackish, arenaceous shales, 7 inches in thickness	$\frac{7}{12}$	$31\frac{2}{3}$

[1]Ibid., p. 66.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Sunbury shale* (?). Blackish, fissile shale, which when weathered is brown, and the outside of the laminæ often of rusty color	$4\frac{1}{3}$	$31\frac{1}{12}$
2.	*Berea sandstone.* Upper surface irregular from weathering of marcasite, as exposed at the dam, and much discolored. Rather massive layers composed of fine-grained quartz sandstone, which weathers to a brownish or rusty color. Splits irregularly; but has been quarried for local use, especially on the opposite side of the pond. At about the middle of the zone are fossils, which are principally inarticulate Brachiopods. Continuation of the sandstone in Pennsylvania, near the State line, that was called the Corry by Dr. I. C. White	$1\frac{3}{4}\pm$	$26\frac{3}{4}$
1.	Thin-bedded, bluish-gray sandstone, composed of fine grains of quartz sand, with some thicker layers, alternating with blue shales continuing from the fall at the dam, down the creek, to below the mill and highway bridge. Some of the layers are ripple-marked. Bottom of formation not reached	25±	25

On the opposite side of the creek from the Hamilton mill a well was drilled at the Robert Hamilton house, which, according to Mr. J. A. Hamilton, obtained water in a rather coarse-grained, soft sandstone at a depth of 60 feet. It is not improbable that this water-bearing horizon is in the Cussewago sandstone, in which case, since the mouth of the well is 25 feet lower than the top of the Berea sandstone, the thickness of the formation is apparently at least 85 feet. A well drilled at a house on the road following the creek, but on the upland, is reported by Mr. Hamilton to have obtained water at a depth of 100 feet, which is probably in the same horizon as the one just described since the topographic map shows that its mouth is some 40 feet higher.

The fauna obtained from the upper fairly thick-bedded course of the Berea sandstone at this locality is an interesting and important one on account of the rarity of fossils in this formation.

Williamsfield Township.—This is the southeastern township of Ashtabula County and lies directly north of Kinsman Township, the northeastern one of Trumbull County. To the east of Williamsfield Township are West Shenango and South Shenango townships of Crawford County, Pennsylvania.

In a run on the W. H. Stanhope farm, two miles south of Williamsfield P. O. (formerly called West Williamsfield) a section was obtained that gave some information concerning the Berea and Orangeville formations.

Section on Stanhope Farm.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Sharpsville lower sandstone* (?). The base of rather fine-grained, buff sandstones, which probably are at or near the base of the Lower Sharpsville.		
3.	*Orangeville formation.* At top, about two feet covered below the superjacent sandstones, when about 3 feet of bluish, argillaecous shale, containing calcareous, concretionary layers is shown	5	100
2.	Largely covered interval; but at the base very black, tough, thin, fissile shale which closely resembles the Sunbury	45	95
1.	*Berea grit.* Rather coarse-grained rock, which contains much iron pyrites, so that the upper surface is rough when weathered. This surface has the usual appearance of that of the Berea, due to the disintegration of the iron pyrites. Lower is an old quarry, which was worked many years ago. At this locality are two runs, and in the one on which the quarry is not located, the top of the Berea is apparently 10 feet higher according to the barometric readings. The rocks at this horizon were described in the writer's field notes as thin-bedded sandstone, with frequent ripple-marked layers, and some blue, arenaceous shales. The upper part rather finer grained and more buff in color than the lower. Just above the sandstone, loose, thin, black shales occur. On this run the lowest exposure of sandstone is 50 feet lower than the outcrop just described. The lowest outcrops seen begin a few rods below the bridge on the Kinsman-Williamsfield highway, and are rather thin-bedded, flaggy sandstones. The layers run from an inch to two inches in thickness; are buff to bluish-gray in color, rather fine-grained, and some of the layers have numerous ripple-marks. It appears probable that some 50 feet of Berea sandstone is passed over in this run without showing the base of the formation	50	50

The black (Sunbury?) shale at the base of zone No. 3 of the above section contains the following species:

1. Lingula melie Hall (c)
   Part of the specimens are of the large form of this species, as for example, one is 11 mm. long and 7.5 mm. wide; which is about the same size as the type specimen represented by fig. 3 on pl. 1, Vol. IV, Pal. N. Y., that is 11 mm. long and 7.2 mm. wide.
2. Orbiculoidea herzeri Hall and Clarke (c)
3. Chonetes sp. (rr)
   A single imperfectly preserved specimen, with semielliptical outline and numerous radiating lines (striæ).

The Berea grit in the old quarry on the W. H. Stanhope farm, zone No. 1 of the above section, also furnished a few specimens of two different species of Pelecypods. On account of the very infrequent occurrence of fossils in this formation in Ohio the listing of any is of interest.

1. Pholadella newberryi Hall (?) .... (rr)
   Two impressions, which apparently represent a small form of this species. The length is about 28 mm. and height 12 mm., instead of 60 mm. and 27 mm., respectively, as given in Hall's description. The formation and locality for this species were given by Hall as the sandstones of the Waverly in Licking County, Ohio.
2. Leda (or Nuculana) pandoriformis Stevens (?) .... (r)
   The specimens are impressions which agree fairly well with the description of this species, except that they are smaller. Their length is 16 mm. and height 8 mm., while Hall, in his description, gave the length as 26 mm. and height as 12 mm. Professor Hall gave the formation and localities of this species as Waverly sandstone of Newark, Ohio, and Battle Creek, Michigan.

The above section apparently shows that in the southern part of Williamsfield Township, the Berea formation is present with a thickness of more than 50 feet, overlying which is the Orangeville formation with a thickness of 50 feet.

Another section was studied on a run crossing the land of C. H. Ford, one-half mile south of Williamsfield P. O. This run shows the same series of rocks that is exposed on the one crossing the Stanhope farm, one and one-half miles to the south, and is as follows:

Section on Ford Run.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Sharpsville lower sandstone* (?). A thin-bedded sandstone, capping a bank of 20 feet of shale, which is probably the base of the Lower Sharpsville sandstone.		
2.	*Orangeville formation.* At top, cliff of 20 feet of shale, in which there are only very shaly sandstone layers, if any sandstone at all. Near the base of the formation is another bank, about 10 feet in height, of bluish-black, argillaceous shale, of which the upper part is rather coarser and blocky. Soft, bluish-gray shale in the bed of the run contains specimens of a small *Lingula*. The contact of the shale with the Berea is not shown	45	80
1.	*Berea sandstone.* Top of the formation not shown; but not far below its top, sandstones occur, which are exposed down the run with a thickness of about 30 feet.		

No.		Thickness. Feet.	Total thickness. Feet.
	This locality is only a few rods above the railroad track. The lower outcrops consist of thin-bedded, bluish, coarse-grained sandstone, with beds of bluish, arenaceous shales. The sandstone is much ripple-marked and similar to that in the Stanhope glen. Base of formation not shown. The Berea sandstone in Ford Run is thin-bedded, shaly, and not massive enough to be of any economic importance	35	35

These outcrops of the Berea sandstone in the streams south of Williamsfield P. O. (West Williamsfield) are interesting, since they clearly fix at this locality the sandstone that Read called the lower member of the Berea. Read described this sandstone and its course across Williamsfield Township as follows: "The lower member [of the the Berea] passing along the higher ground, east of the Pymatuning, follows the course marked by the northern green line on the map, leaving the state somewhere near the northern part of Williamsfield, but is there covered with drift. It is exposed in several points near the old state road south of West Williamsfield; is there a coarse sandstone in thin layers, spotted with iron, and was used by the early settlers for grindstones. The lower part of the Berea is here comparatively thin and probably not of much economical value, although deserving a further exploration to test its extent and character."[1] The old State road mentioned by Read is the Kinsman-Williamsfield road crossing both of the runs described above at the horizon of the Berea formation, which is the only sandstone of considersble thickness shown on them, so that there can be no doubt that in this locality Read's lower member of the Berea is the Berea formation. As described by Read it agrees not only in its location, but in its lithologic characters as well.

On the State road above and below the center of Williamsfield P. O. the Berea sandstone is shown. On the direct road from Williamsfield P. O. to Williamsfield (formerly called the Center) about one-half mile east of lower turn in Williamsfield P. O., the top of the Orangeville formation and base of the Lower Sharpsville sandstone are shown by the roadside. There is a small covered interval so that the exact contact of the two terranes is not shown. Below the highway in Walnut Run, the Orangeville shale is rather well exposed. This locality is by the W. T. Belts or Walnut Run farm, and the section down the run is as follows:

Walnut Run Section in Williamsfield P. O.

No.		Thickness. Feet.	Total thickness. Feet.
4.	*Sharpsville lower sandstone.* Thin-bedded sandstones shown by roadside	--	--

[1]Geol Surv. Ohio, Vol. I, p. 508.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Orangeville formation.* Largely dark, bluish shale in upper part of formation. Lowest outcrop in gutter on east side of the railroad track at Walnut Run, where the shale is almost black in color and rather tough	50	60
2.	Covered interval	10	10
1.	*Berea sandstone.* Contact of sandstone and shale not shown, but the covered interval is only 10 feet. Thin-bedded sandstones shown in side of Walnut Run, below the railroad fill. A little farther down the stream, in its bank, about 3 feet of thin-bedded, flaggy sandstone is shown, which is moderately coarse-grained, and some of the layers have conspicuous ripple-marks. Twenty feet lower than the first sandstones exposed, the State road crosses Walnut Run in the lower end of Williamsfield P. O., just south of the S. B. Ford house.		

This stream gives a thickness of at least 50 feet for the Orangeville formation, to which may belong part of the covered 10-foot interval. The course of the run, however, is to the southwest, and perhaps the dip increased the thickness a little.

A stream about one-half mile north of the northern part of Williamsfield P. O. and crossing the State road just north of the house owned by Wm. Clark, in which A. B. Daniels lived in 1910, gave a most interesting section of the Berea formation.

Section one-half Mile north of Williamsfield P. O.

No.		Thickness. Feet.	Total thickness. Feet.
9.	*Orangeville formation.* Black shale in side of bank, several rods above the railroad fill; and in bed of run below this bank, thin layer of sandstone. Below the railroad fill, black shale in bed and on bank of run. At the point where the top of the Berea sandstone occurs, in the bed of the run, there is on the northern side of the stream a bank of 7 feet of fine, argillaceous shale, which is mainly bluish-black, weathering to a rusty color. There is an occasional thicker layer in the upper part of the bank. The lowest shales are very dark in color, and in these *Lingula melie* Hall and a larger species of *Lingula* are not uncommon. One layer, a few inches above their base, contains an immense number of broken *Lingula* shells, which retain their shelly material	12	$85\frac{1}{2}$
8.	*Berea sandstone.* Top of the sandstone occurs in the bed of the stream, not far below the railroad fill, and it contains numerous pits, caused by the weathering out of nodules of marcasite and iron pyrites. These upper sandstones are bluish-gray to buff in color, weathering brownish, composed of rather fine grains of quartz		

No.		Thickness. Feet.	Total thickness. Feet.
	sand; are thin-bedded and split up rather unevenly. They are only 2 or 3 feet in thickness and correspond to the Corry sandstone of Dr. I. C. White in western Pennsylvania. Below are much thinner bedded sandstones to shaly sandstones and shales. The thin sandstones in this zone are much ripple-marked. There is an occasional layer of bluish-gray, fine-grained, quartz sandstone 6 inches or so in thickness. These thicker layers weather to a brownish color and are not so very different in lithologic appearance from those of the Berea formation as shown in the Lithopolis glen, southeast of Columbus, in central Ohio	10	$73\frac{1}{2}$
7.	Zone of several layers of sandstone from 4 to 6 inches thick, which split into 1- to 2-inch layers. It is bluish-gray, weathering to a brownish gray, and coarser grained, quartz sandstone than those above, containing some clay pebbles. A little higher than the base are some small and old quarries. This zone occurs a few rods above the State road, and is from 3 to 5 feet in thickness	3+	$63\frac{1}{2}$
6.	Shaly sandstone to shales, which are blue in color, and shown on the stream bank a short distance above the State road. Some of the shale is argillaceous; but part of it is arenaceous, containing grains of white quartz sand. Some of the thin, irregularly bedded sandstones are ripple-marked, and $3\frac{1}{2}$ feet or more of this zone is shown on the bank of the run. The rocks of this zone more closely resemble lithologically the Bedford, than those of most of the section	$3\frac{1}{2}$	$60\frac{1}{2}$
5.	Covered interval, both above and below the highway	15	57
4.	Thin-bedded, micaceous sandstones, which are greatly ripple-marked, and composed largely of grains of rather fine, quartz sand. In some of the layers the quartz grains are fairly coarse, especially in the lower part of the zone. They contain considerable marcasite, and certain layers are decidedly blue in color, although part are buff. There is a great number of ripple-marked layers, and the ripples run in different directions on different layers	10	42
3.	Covered zone	10	32
2.	Thin-bedded, coarse-grained, quartz sandstone	1+	22
1.	Top of massive Cussewago sandstone, as shown in bed of run. A massive, buff, quartzose sandstone, which is very friable, with the lithologic appearance of the Cussewago sandstone of western Pennsylvania. When wet in the bed of the stream, the sandstone is much more friable than when dried out on the higher bank of the run. There are harder layers, which are thinner, alternating with the soft ones, and it also contains some clay ironstone pebbles. When wet the color is rather greenish-buff, but light buff when dry. The lowest		

No.		Thickness. Feet.	Total thickness. Feet.
	outcrop occurs in the bed of the run a few rods above the bridge on the first east and west road north of Williamsfield P. O. The interval along the run, from the top of the coarse-grained deposits down to the lowest exposure, is partly covered, although there are cliffs of sandstone on the southern bank which must practically overlap, so that all of it may not have this lithologic character. By the level, 21 feet was obtained for the thickness of this zone, while the barometer gave 20 feet	21	21

In the above section the total thickness of the several zones from the base of the lowest outcrop of sandstone to the top of the Berea formation amounts to 73½ feet. The thickness of the greater part of this interval was obtained from barometric readings. At another time readings taken at the lowest exposure of sandstone on the run and the top of the Berea formation, with an interval of only 20 minutes between them, gave a difference in altitude of 95 feet. This is believed to be the more accurate determination for the thickness of the entire section, since the topographic sheet indicates a thickness of 80 feet or more for this interval, but the subdivisions of the section were made on the former one, and consequently that has been used in the detailed section. In fact, still a third reading at top and bottom gave an interval of 105 feet, but it is thought that this is too great. Again, the direction of the stream is to the southwest, and the distance from the top to the bottom of the sandstone about three-fourths of a mile, so that perhaps the dip has increased a little the apparent thickness of the Berea formation. The rocks along this run were better shown when it was first studied in 1904 than when it was reviewed in 1910. The section, however, is a most important one for the Berea formation in eastern Ohio, since it shows that it has a thickness of at least 73½ feet and probably of more than 80 feet.

In 1910 the lower portion of the above section was almost continuously shown and the following measurements were made. This section began with the lowest exposure in the bed of the run, then a little farther up stream followed a gully to the highway on the south and then for a short distance along this road gutter.

No.		Thickness. Feet.	Total thickness. Feet.
3.	Upper layers as shown in highway gutter, fine-grained sandstone, 2 feet or more in thickness, and lithologically not very different from sandstones of the Bedford. Remainder of zone composed of thin-bedded, coarse-grained, quartz sandstone and the layers frequently ripple-marked	9	22

No.		Thickness. Feet.	Total thickness. Feet.
2.	Layer of coarse-grained sandstone containing numerous clay pebbles	1±	13
1.	Thick-bedded, massive, very soft, coarse-grained, quartz sandstone. Typical *Cussewago sandstone*	12±	12

This last section apparently corresponds to the lower zone of the section along the run, but perhaps it extends stratigraphically a couple of feet or so higher. It shows that above the lower 12 or 13 feet the rock is not massive, but thin-bedded, although still composed of rather coarse grains of quartz sand.

The writer has used the name Cussewago sandstone, which was given by Dr. White in 1881 to a sandstone along the Cussewago Valley in Crawford County, Pennsylvania, for the lowest zone of the Berea formation in the above sections because of its lithologic resemblance to that sandstone and similar stratigraphic position, which will be shown in sections between this locality and the typical ones in the Cussewago Valley. Dr. White described the Cussewago sandstone in its typical region as a "very peculiar rock (commonly of a buffish-brown color) is quite coarse, and in many places contains pebbles; but its sand grains cohere so loosely that the seemingly massive rock crumbles after a short exposure to a bed of sand. . . . . From French Creek to the Ohio line it can generally be traced by the sand along its disintegrated outcrop."[1]

Furthermore, Dr. White stated that "its *color* is not always buff-brown; occasionally it is dark-green or greenish-blue. . . . . . *Flat quartz pebbles* are seen in it at many localities."[2]

In the eastern part of Williamsfield Township and three-fourths of a mile west of the State line is a ridge on which are large blocks of Sharon conglomerate. There is an old pit where the rock was once quarried, but it is much shattered and has apparently been undermined. The base of these blocks according to the barometric reading is only about 65 feet higher than the top of the Berea sandstone at Williamsfield P. O. This ridge is west of Turner Station on the Oil City Branch of the Lake Shore and Michigan Southern Railroad. This outcrop was known to Read who wrote as follows concerning it: "In the east part of Williamsfield, a high ridge is capped with the Conglomerate, which has supplied a large part of the stone used in building in that part of the county. It is in blocks and masses of large size, but evidently much below its geological horizon, having resisted the pulverizing and denuding agencies which have removed the strata below it."[3]

[1]Second Geol. Surv. Pa., Q^4, p. 95.
[2]Ibid., p. 96.
[3]Geol. Surv. Ohio, Vol. I, p. 483.

Greene and West Shenango Townships, Pa. — Some time was given to searching for outcrops on the Pennsylvania side of the line in Greene and West Shenango townships, which lie directly east of Kinsman and Williamsfield townships, Ohio; but without much success. On the Crawford-Mercer County line, one mile east of the State line on Snodgrass Run on the farm of V. Hitchcock, are bluish, compact flaggy sandstones which are considered the Lower Sharpsville. The base of these sandstones is on the run a few rods south of the road, and there is a calcareous and iron concretionary layer just above the base. This sandstone has been quarried slightly by Mr. V. Hitchcock. Farther down the run is a bank of bluish shale with layers of sandstone an inch or so in thickness, which is some 15 feet high. This shale bank without much doubt represents the upper part of the Orangeville formation. One-half mile farther down the run at the cross-road, banks of shale some 30 feet in height are reported, but no outcrops of sandstone beneath the shale had been noted. On the road between Tannersville and Jamestown, where the railroad crosses the largest stream, are cuttings by the roadside showing 10 feet or more of the Orangeville shale. This is probably Snodgrass Run, on which farther up stream the outcrops were studied on the farm of Mr. Hitchcock.

West of Brockway Corners on a run in the northwestern corner of Mercer County are apparently quarry pits. Blocks of stone probably from them are fine-grained, bluish to buff in color, as weathered, and resemble lithologically the Sharpsville sandstones. At the first four corners in Ohio west of Brockway's, in a small stream on the Fred Allen farm in the northern part of Kinsman Township, is an outcrop of Sharpsville sandstone.

The outcrops on Snodgrass Run on the farm of V. Hitchcock are about one mile east of the Floch farm in West Shenango Township concerning which Dr. I. C. White wrote as follows: "The *Sharpsville Upper Sandstone* has been quarried near the southwestern corner of the township to a considerable extent on the land of Mr. Floch. It is made up of thin layers of sandstone from 4″ to 18″ thick, some of which make very good flagging.

"This is the locality where the *Berea Grit* of Ohio was supposed to pass into Pennsylvania, being wrongly identified with the *Sharpsville Sandstone*; but the true Berea Grit is to be found 100′ lower in the series; being probably the 20′ sandstone struck at a depth of 90′ in the Gibson well near Jamestown."[1] There is some mistake concerning the location of the above mentioned quarry, since Mr. Floch states that there has never been one on his farm or in that vicinity.

There is some uncertainty in the later accounts as to which sandstones are to be correlated with Read's two members of the Berea. As

[1]Second Geol. Surv. Pa., Q^4, p. 155.

has been shown under the account of Vernon Township, Dr. White correlated the Shenango and Sharpsville sandstones respectively with the upper and lower members of the Berea. This correlation for that township appears to be justified by Read's description of the Berea grit in Vernon, which he stated is "exposed in massive layers, from which blocks of any desired dimensions may be taken. It is here firm and strong, but contains nodules of iron ore which will be likely to color the stone and detract from its value if used for building purposes."[1] The above lithologic description of the rock when considered in connection with the fact that the true Berea was not seen in that township, apparently proves that it was the Shenango sandstone that Read was describing.

On Read's geological map the Berea is represented as dividing in the northern part of Vernon Township, the upper member represented by the eastern green band passing across the southeastern part of Kingsman Township into Pennsylvania. This of course agrees with the correlation of that member with the Shenango sandstone, since this sandstone outcrops on Mill Creek, in the southeastern corner of Kinsman Township and also to the east in Pennsylvania. On the other hand, Read in his description of the distribution of the Berea states that "the upper part of the Berea passes out of the state near the north-east corner of Kinsman, the lower member passing along the higher ground, east of the Pymatuning, follows the course marked by the northern [western] green line on the map, leaving the state somewhere near the northern part of Williamsfield, but is there covered with drift."[2] The writer has thought that perhaps the words "north-east" are a typographical error for southeast corner of Kinsman, in which case Read's description of the Berea will agree with his map. Dr. White did not state with which member of Read's Berea sandstone he correlated this Sharpsville upper sandstone of West Shenango Township. There seems to be no question but that the outcrops south of West Williamsfield, which Read referred to his lower member of the Berea, are genuine Berea; but his representation of the distribution of his lower member of the Berea on the map agrees better with that of the Sharpsville sandstone, since it is represented as making a curve across the northern part of Williamsfield Township and entering Pennsylvania. Later it will be shown that the Berea sandstone, the one seen in the outcrops south of West Williamsfield, follows the ridge northerly to West Andover in Andover Township which adjoins Williamsfield Township on the north, and enters Pennsylvania at Pennline Village, on the State line between Conneaut Township, Pennsylvania, and Richmond Township (the next one north of Andover) in Ohio. It appears certain that Read in different localities referred both the Berea and Sharpsville

[1] Geol. Surv. Ohio, Vol. I, p. 505.
[2] Ibid., p. 508.

sandstones to what he called the lower member of the Berea, and if he intended to say that the upper member "passes out of the state near the north-east corner of Kinsman" then it is also apparent that in different localities he referred both the Sharpsville and Shenango sandstones to this upper member of the Berea.

Professor Cushing in discussing the distribution of the Berea stated that "in tracing its outcrop to the east, Mr. Read, when near the state line, came upon three sandstones near this horizon all resembling some lithological phases of the Berea. He concludes that the Berea here has split into two parts, or possibly even into three."[1]

South Shenango Township, Pa.—To the east and north of West Shenango Township is South Shenango Township, on the southern border of which in the valley of the Shenango River lies the city of Jamestown. This portion of the river valley is bordered by fairly steep hills and the streams descending from the higher ground afford many outcrops of the Mississippian rocks. The region has been carefully described by Dr. White, and it was visited for the purpose of becoming familiar with the distinguishing characters of some of the terranes which he has named and described in western Pennsylvania.

The first section in this township described by Dr. White is one beginning on the land of Mr. James Snodgrass to the northeast of Jamestown and following down a ravine past the stone quarries, which he called the "Snodgrass' Section."[2] This section was somewhat carefully examined and some description of it for comparison with the Ohio sections is deemed of importance.

Snodgrass Section.

No.		Thickness. Feet.	Total thickness. Feet.
9.	*Sharon sandstone.* Coarse, micaceous, quartz sandstone gray color in general, but some of it bluish, without any clay ironstone pebbles. In general, the layers are fairly massive, although there is a tendency for some of it to split into flaggy ones, especially in the lower portion. It is apparently an old quarry, although it had been worked to some extent during the summer of 1904. From the lowest appearance of the sandstone in the run to the top of the quarry is 17 feet as leveled.	17	284
8.	*Shenango shale.* Bluish shales and thin sandstones; but partly covered interval. Two readings of the barometer gave 40 feet interval in each case	40	267
7.	*Shenango sandstone.* Composed largely of quartz grains, cemented by iron, and also contains numerous pebbles of clay ironstone of various sizes. Some of them are rather small and others were seen several inches in diameter. The stone is apparently somewhat brownish-		

[1]Proc. Am. Assoc. Adv. Sci., Vol. XXXVI, p. 215.
[2]Second Geol. Surv. Pa., Q^4, pp. 150, 151.

No.		Thickness. Feet.	Total thickness. Feet.
	gray where not discolored by weathering; but from the latter cause it is usually buff to brownish in color. Some Brachiopod shells were seen, but as a rule they are poorly preserved. This sandstone can be distinguished from the Berea by its rougher feel, clay ironstone pebbles and more abundant Brachiopod shells. From the top of the shale, at the base of the fall, to the top of the sandstone in the old quarry, is 13 feet. The thickness of the Shenango sandstone is given as 15 feet in Dr. White's section.[1] This outcrop is on the Gamble farm, in a fall just below the Jamestown-Adamsville road bridge, one mile northeast of Jamestown	13	227
6.	*Meadville upper shale.* About 1½ feet of blue shale shown at the base of the fall, under the Shenango sandstone. Lower, are bluish shales, and thin, flaggy sandstones, on some of which are ripple-marks. The interval is partly covered	27	214
5.	*Meadville upper limestone.* A blue, compact stratum which is apparently somewhat calcareous; but on the weathered outcrop looks more like a sandstone. However, blocks blue in color, strongly calcareous, and containing fish fragments, were found	1±	187
4.	*Meadville lower shale.* Blue shales and thin sandstones. *Sharpsville upper sandstone.* Fine-grained, rather buff-colored sandstones. Partly concealed interval, and line of separation not clearly shown. The thickness of this interval is the same as that given by Dr. White, who called it all "*Sharpsville Upper Sandstone*" in his section	95	186
3.	*Meadville lower limestone.* Blue, hard, compact, silicious limestone, which, on weathering, forms a brownish layer on the outside, due to iron, as stated by Mr. J. T. Hodge, who first described it.[2] It forms the floor of the run for a short distance, and breaks into blocks showing a glassy fracture. On weathering, the edges are somewhat rounded, and the blocks are rather conspicuous in the streams, especially as washed down them. The outcrop in this stream does not differ much from the one in the Boyer Glen, one mile south of Hayfield, Crawford County, Pa., which is described farther on in this bulletin (pp. 721-723)	1½±	91+
2.	*Sharpsville lower sandstone.* Fine-grained and buff-colored sandstone, only 5 feet of which is shown in the run	5	90
1.	Concealed to Pittsburgh and Erie Railroad station at Jamestown	85	85

A run on the Mathew McElhaney farm 1½ miles north of Jamestown,

[1]Ibid., p. 150.
[2]Pa. State Geol., 3d Ann. Rept., 1837, pp. 111,112. Also see Geol. of Pa., Vol. I, 1858, p. 584; and Second Geol. Surv. Pa. Q^4, 1881, pp. 87, 88.

descending from the highland to the Shenango, cuts down to the Shenango sandstone and also exposes some of the subjacent rocks. This locality was also described by Dr. White under the heading of the "McElhany Section."[1]

McElhany Section.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Shenango sandstone.* Brownish-gray or brownish sandstone, composed of coarse, quartz grains, with numerous iron ball concretions. Has been quarried to some extent. Dr. White gave thickness as 20 feet	20	40½
2.	*Meadville upper shales.* Blue shales, with a thickness of 20 feet according to Dr. White. A single reading of the barometer gave 30 feet for these two intervals. In basal shales a few fossils were found, as *Camarotœchia* and a Pelecypod	20	20½
1.	*Meadville upper limestone.* Bluish, impure limestone, containing flattened pebbles of shale and fragments of fish	½	½

West Fallowfield Township, Pa.—This township lies directly east of South Shenango Township, and the plateau capped by the Sharon conglomerate in the latter one extends across the line into the southwestern corner of West Fallowfield Township. Crooked Creek flowing south forms the greater part of the eastern boundary of West Fallowfield Township and receives a number of tributaries from the higher ground to the west. One of these flows through the small village of Adamsville and affords a section of the Mississippian rocks that has been described by Dr. White under the name of the "Adamsville Section,"[2] and which, like the section near Jamestown, was studied for the purpose of becoming well acquainted with the terranes described by him in northwestern Pennsylvania.

Adamsville Section.

No.		Thickness. Feet.	Total thickness. Feet.
8.	*Shenango sandstone.* The more massive sandstone is brownish-gray, and composed to a large extent of quartz sand. Some of the more flaggy stone is of blue color, and finer grained. The ironstone concretions are very numerous in some parts of the outcrop. A few fossils were found as *Camarotœchia*, *Productus* (?), *Orbiculoidea*, etc. This outcrop makes the fall in the stream to the west of Adamsville	8±	130½
7.	*Meadville upper shales.* They are composed in the upper		

[1]Second Geol. Surv. Pa., Q^4, p. 154.
[2]Ibid., p. 149.

No.		Thickness. Feet.	Total thickness. Feet.
	part of bluish, arenaceous shales, which alternate with bluish-gray, micaceous sandstones, the layers varying from a fraction of an inch to perhaps two inches in thickness, and some of them are ripple-marked. Some of the layers contain iron and are also slightly calcareous, perhaps of concretionary character. These shales are well shown below the Shenango sandstone in the fall	22	122½
6.	*Meadville upper limestone.* Bluish-gray in color, containing flattened shale pebbles and fragments of fish	$\frac{7}{12}$	100½ +
5.	*Meadville lower shales.* Bluish shales and thin, flaggy sandstones, which are occasionally ripple-marked	34	100
4.	*Sharpsville upper sandstone.* The sandstones are fairly thin-bedded, buff in color, fine-grained and rather micaceous. There is an occasional iron nodule. The fineness of grain separates this sandstone from the Shenango and Berea, and the comparative absence of iron balls and fossils separates it from the Shenango sandstone	40	66
3.	*Meadville lower limestone.* "A very hard calcareo-siliceous rock, jutting out of the bank of the stream, and scattered in large masses, with rounded angles along its bed," as described by Dr. White[1]	1±	26
2.	*Sharpsville lower sandstone.* Flaggy sandstones, with some shales and calcareous, concretionary layers, a very conspicuous one at the base	15	25
1.	*Orangeville shales.* A few feet of drab, argillaceous shales, which are at the top of the formation	10±	10

Perhaps the thickness given for the above section is less than the true thickness, since on Dr. White's section the interval from the base of the Sharpsville lower sandstone to the top of the Shenango sandstone is 130 feet, while on the writer's it is given as 120 feet. Again, a reading of the barometer at the base of the exposed Orangeville shales and the top of the Shenango sandstone gave a difference of 160 feet, while on the section it amounts to only 130½ feet.

Andover Township.—This township lies directly north of Williamsfield Township and west of South and North Shenango townships, Crawford County, Pennsylvania. The steep ridge east of Pymatuning Creek crosses the township from north to south along its western border, and some of the streams descending from the higher ground to the Pymatuning Valley cut through the surficial deposits, exposing the underlying Mississippian formations.

A section was studied which is located near a school-house in the southwestern corner of the township on an eastern branch of a larger run crossed by the State road. This run is two miles south of West

[1] Ibid., p. 150.

Andover and about one-half mile north of the township line on the farm of Charles C. Gay, while the section is down the run from the watering trough.

Section on the Charles C. Gay Farm.

No.		Thickness. Feet.	Total thickness. Feet.
2.	*Berea sandstone.* Layers of buff sandstone, showing some ripple-marks, which are both thinner bedded and finer grained than those of zone No. 1, but composed largely of grains of quartz sand. Old quarries in middle of upper part of this zone. Lower portion of zone partly covered	35	$37\frac{3}{4}$
1.	In bed of run, coarse, quartzose sandstone which contains some quartz pebbles the size of peas. This zone has the lithologic characters of the Cussewago sandstone.	$2\frac{3}{4}$	$2\frac{3}{4}$

Another section was examined in a run just north of the house of Henry A. Lewis. The section is as follows:

Section on the Henry A. Lewis Farm.

No.		Thickness. Feet.	Total thickness. Feet.
1.	*Berea sandstone.* Ledge of thin-bedded, buff sandstone, near watering trough. In this part of the zone are old pits, in which the rock was formerly quarried. In the lower part of the zone are arenaceous shales to thin-bedded sandstones; but it is not so shaly as most of the corresponding interval in Pennsylvania to the east of Conneautville. Coarse-grained, very friable sandstone, with the lithologic appearance of the Cussewago sandstone	45	45

In the bed of another run farther north, very coarse-grained, soft, buff sandstone was found which contained some quartz pebbles the size of peas. This lower zone has the lithologic characters of the Cussewago sandstone. In a small branch of the same run 45 feet higher are thin-bedded buff sandstones.

Another outcrop of the thin-bedded portion of the Berea formation is shown in a run a few rods north of C. A. Kingsley's house on the State road, one-half mile south of West Andover. About 8 feet of rather buff thin-bedded sandstone is shown in the run below the highway bridge. It is composed mainly of fairly coarse grains of quartz sand, is micaceous, the layers about an inch ($\pm$) in thickness and some of them have beautiful ripple-marks. Above the highway the layers of buff sandstone are still thinner so that some of it is rather shaly. The grains of sand are coarse and some of the layers are rippled-marked. Altogether at least 15 feet of these thin-bedded sandstones are shown in this run, counting both those below and above the highway.

On the road from West Andover up the hill toward Andover are outcrops of sandstone which extend nearly if not quite to the summit of the slope, and from them the following section was constructed:

Section along Highway East from West Andover.

No.		Thickness. Feet.	Total thickness Feet.
4.	*Berea sandstone.* Small pit on the Martin McNally farm where sandstone was quarried by Mr. B. F. Perry for the foundation of his house. This locality is about one-fourth mile north of the West Andover-Andover highway, and about one-half mile northeast of West Andover. The sandstone is dotted with small rusty spots (something like those of the Shenango sandstone), and there are also large rusty spots. This pit is at about the same elevation as the summit on the highway. In the highway gutter, 5 feet lower than the road summit, is a bed of massive, coarse-grained sandstone, which is very friable. This rock shows large iron spots similar to those noted in the Perry pit, and occurs above and east of the F. M. Wilder house and furniture shop	5±	160
3.	Thin-bedded, coarse-grained, buff sandstone exposed in gutter and by road side, down the hill into West Andover. The zone is partly covered; but in the lower part includes some coarse-grained, massive sandstone, which is very soft, the apparent base of which was taken for the base of this zone. This lower sandstone has the lithologic appearance of the Cussewago	45	155
2.	At the base of this zone thin-bedded, buff, shattered sandstone by roadside, just above four corners in West Andover	10	110
1.	Covered interval from West Andover down to the bridge over Pymatuning Creek	100	100

The above section indicates some 60 feet, barometric measurement, for the Berea formation on this hill slope, without showing either the top or bottom of the formation. The data for this section were secured in 1904 and in 1910 it was seen that the gutters, in general, were filled with dirt so that the older rocks were scarcely exposed, if at all.

From loose pieces of sandstone beside the road in West Andover which probably came from the Berea, although it is possible that they might be from the Cuyahoga, were collected a few specimens of poorly preserved fossils. A single impression of *Camarotœchia* sp. was found which has from 16 to 18 plications and is apparently similar to *C. sageriana* Winch. Another specimen is a fragment of apparently a *Spirifer* with a plicated sinus, and in addition there are imperfect impressions of two or more Pelecypods.

About three-fourths of a mile north of West Andover is a high hill

known as Little Mountain, but given on the topographic sheet as Owens Hill. The barometer gave its summit as 130 feet higher than the basal outcrop of sandstone in West Andover, or 135 feet higher than the four corners in that village. This elevation can not be far from correct, since the topographic sheet gives a difference of at least 130 feet for the same interval. There are numerous boulders of crystalline rocks on the slope of the hill; but no outcrops, although many small blocks of fine-grained, buff, somewhat micaceous sandstone occur.

These blocks of sandstone are also thrown out of the numerous woodchuck holes on the hillside and have the lithologic appearance of the Sharpsville. The summit of this hill is some 70 feet higher than the highest outcrops of the Berea sandstone noted on the highway east of West Andover, and it appeared to the writer, when in the field, not improbable that the Sharpsville sandstone formerly extended to this hill and had protected the softer underlying shales from erosion. If this be true then it represents the extreme northern outlier of the Sharpsville in Andover Township. Later the writer found a reference apparently to this hill by Mr. Frank Leverett who called it one of the knolls of the Cleveland moraine.[1] The highway cut on the east and west road to the north of the hill shows only drift, which perhaps corroborates the latter interpretation of its origin.

Buff, very coarse-grained sandstone occurs by the roadside one mile north of West Andover and also in a small stream, both of which outcrops are just north of the first road turning west. About 3½ feet of rock is shown in the small quarry pit, and some of it contains a considerable quantity of white quartz pebbles, part of which are nearly flat. This rock is lithologically much like the Cussewago sandstone, except that some of it is very hard from the large amount of iron contained in it, serving as a cementing material. In 1910 scarcely any rock was shown in the quarry; but on the highway between the two runs coarse-grained quartz sand rock of brownish color was exposed. In the road, evidently weathered from the sandstone, were loose pebbles of white quartz. About these small hills are runs and marshy places fed by springs coming out of the sandstone.

At Leon, 3¼ miles north of West Andover, in the southwestern corner of Richmond Township, which is the one directly north of Andover, blue flags are reported at a depth of 35 feet beneath the surface.

From loose blocks in a draw about one mile northwest of Leon the following species were collected:

1. Spirifer disjunctus Sowb.
2. Strophalosia muricata (Hall) Beecher
3. Camarotœchia contracta Hall
4. Productella sp.

[1]Mon. U. S. Geol. Surv., Vol. XLI, 1902, p. 630.

In the road gutter, just north of the house of B. F. Ayers and about two miles north of Andover, is a very coarse-grained greenish-buff, friable sandstone. The lower part contains a considerable number of white quartz pebbles and 12 feet or a little more of the sandstone is shown. This outcrop is really on the bank of the neighboring stream, and both above and below the road are pits where sand has been dug. It reminds one somewhat of Dr. White's description of an outcrop of the Cussewago sandstone near Summit Station on the Pittsburgh and Erie Railroad in Conneaut Township, Crawford County, Pennsylvania, between 9 and 10 miles northeast of the locality just described, where he stated "it can be shoveled like beach sand, and I should have mistaken it for Drift, but for shales and sandstone layers overlying it in place."[1]

The eastern and northern portions of Andover Township show very few outcrops of Paleozoic rocks and the extreme eastern part of the township is bordered by the Pymatuning swamp, which extends for miles along the Shenango River. A well on the C. W. Butler farm east of Andover is reported to have struck solid rock at a depth of 10 feet. The greater part of the 10 feet is blue clay with gravel at the bottom. Another one across the road at this locality is reported as 67 feet deep. Rock which is called hard was struck in a well on the Henry S. Butler farm at a depth of 11 feet.

Andover Wells.—An oil well was drilled to the depth of 2,662 feet on the farm of G. W. Swezey about one-half mile slightly west of north of the Andover square. The drilling was finished in March, 1904. The mouth of the well is located near a small run and according to the barometer is 15 feet lower than the Andover railroad station, which is at about the same elevation as the Andover geodetic station; the latter is 1,091 feet above sea level. The banks of the run near the well are very sandy, but no solid rock was found in place. There are small pits where sand has been taken out. Mr. Morey thinks no sandstone was struck in the upper part of the well, because he drilled a railroad well for water to the depth of 108 feet which is located only a short distance away across the railroad tracks and no sandstone was struck.

This account is probably not correct, since Mr. Hill, who has charge of the railroad wells at Andover, said that they pass through 40 feet of clay (no shale), when the top of a sandstone is reached that is almost white in color, which was penetrated to a depth of 35 feet. All the wells in the town near this depth he said reach this sandstone and none of them has gone through it. There is a good volume of water obtained, which supplies the railroad wells and many in the town. Water is obtained very soon after entering the sandstone, but the volume increases on going somewhat deeper. The water is very pure according to the analysis for the railroad.

[1]Second Geol. Surv. Pa., Q^4, p. 95, f. n.

A partial set of samples of the drillings from the oil well were kept by Messrs. M. F. Covell and Fred M. Smiley, which they kindly allowed the writer to examine, and the following record is compiled from these two sets of samples:

Record of Andover Well.

Depth. Feet.	Description of Sample.
530 (?)	Sample of black shale, with brownish streak, thought by Mr. Covell to be from the gas horizon, which Mr. Smiley gave as 530 feet down; but the depth is questioned. Chips of bluish shale giving a white streak are found with the lower samples. Mr. Smiley reported that limestone was struck at a depth of 2418 feet; but no samples examined were marked as from this depth.
2500	*Onondaga limestone.* Light gray limestone, effervesces strongly in cold, dilute HCl. Some chips of blue shale from above.
2560	Light gray, very calcareous limestone, strong effervescence in cold HCl. Some chips of blue shale from above.
2575	Very light gray sample, fine chips with strong effervescence in cold HCl.
2580	About the same as above.
2600	Light gray, almost white, very fine chips, strong effervescence in cold HCl.
2605	Darker gray limestone, strong effervescence in cold HCl. A number of large chips of blue shale mixed with the others.
2609	Rather dark gray limestone, fine chips and strong effervescence.
2611	Similar limestone to above, only not quite so dark colored.
2613	Light gray limestone, very strong effervescence.
2614	Somewhat darker colored limestone, but strong effervescence.
2615	About the same as above, only a little lighter colored. It contains some large chips of blue shale.
2620	Light gray to drab limestone, which has somewhat weaker effervescence in cold HCl.
2625	About the same color as above, but with stronger effervescence. A good many chips of blue shale.
2630	About the same color, fair effervescence in cold HCl; but stronger on heating, which shows $MgCO_3$ and $CaCO_3$.
2640	Very light gray color, fine chips with fairly strong effervescence in cold HCl; but leaving a considerable residue.
2652	Sample as a whole is somewhat greenish-gray in color; but under a microscope a large proportion is composed of white quartz grains. Very slight effervescence in either cold or warm HCl. At this depth Mr. Smiley reported the oil sand, and he thinks some 5 barrels of oil were baled out of the well. *Sylvania sandstone?* Mr. Smiley had a sample composed of white quartz sand, labeled as from a depth of 2640, another composed of finer quartz sand than the above, and slightly brownish from rust, marked as from 2640, and also a third marked as from 2656, which was composed of quartz grains, slightly brownish from rust.
2660	Almost white sample, composed of fine grains of quartz sand.

Depth. Feet.	Description of Sample.
	Apparently from a very pure quartz sandstone. Scarcely any effervescence in either cold or warm HCl.
2662	Brownish-gray sample in the mass; but a microscope shows it to be composed of small chips of light gray to drab limestone. Moderate effervescence in cold HCl, which is increased on heating.
	Bottom of well.

The collection in Mr. Covell's possession shows a white sandstone 10 feet thick almost at the bottom of this well, which perhaps represents the Sylvania sandstone of northwestern Ohio. The samples in Mr. Smiley's possession as marked would indicate that this sandstone was reached at a depth of 2,640 feet and continued nearly to the bottom of the well, or 2,662 feet. A sample of the oil from this well and supposed to be from the sandstone at a depth of 2,656 feet is rather light in gravity, of greenish color in dim light; but amber colored by transmitted light.

At the Arlington Hotel in Andover, a well was drilled to the depth of 86 feet, according to Mr. Hahn, who furnished the following information concerning it. The upper portion of the well is in quicksand, at the bottom of which is a blackish shale which the drillers called the Erie shale. At the depth of about 46 feet a sandstone was struck, the upper part of which is of rusty color; but the lower part is a very white sand. The well was drilled into this sandstone for about 40 feet without reaching its bottom. The mouth of this well is at about the same level as the railroad in Andover.

Richmond Township, Ohio, and Conneaut Township, Pa.—Richmond Township lies directly north of Andover Township, but outcrops of the Paleozoic rocks are not frequent. To the east are North Shenango and Conneaut townships, in Crawford County, Pennsylvania, and some time was given to an examination of the outcrops in Conneaut Township for the purpose of tracing the outcrop of the Berea formation from Ohio across the State line into Pennsylvania. In the northwestern part of the township on a run entering the West Branch Ashtabula River, rocks are shown just below the highway bridge on the Thomas Flack farm. This locality is on the first road turning east toward Richmond Center from the one leading south from Steamburg Church, and nearly 1½ miles southeast of this church. In the summer of 1910 blue shales and bluish-gray sandstones had been dug out of the stream just below the highway bridge. The thin-bedded sandstones contain fossils, of which the most abundant species is *Spirifer disjunctus* Sowb. Some specimens of *Euomphalus hecale* Hall were also collected. The complete list is as follows:

1. Spirifer disjunctus Sowb. .... (c)
2. Camarotœchia contracta Hall .... (r)
3. Camarotœchia orbicularis Hall .... (rr)

4. Strophalosia muricata (Hall) Beecher .... (c)
5. Productella lachrymosa (Con.) Hall (?) .... (rr)
6. Productella lachrymosa (Con.) Hall var. lima Con. .... (rr)
7. Liorhynchus sp. .... (rr)
   Internal impression of a large specimen.
8. Pterinopecten neptunis Hall (?) .... (rr)
9. Euomphalus (Straparollus) hecale Hall .... (r)

Three-fourths of a mile farther east the road crosses the West Branch Ashtabula River; but it is only a ditch in soil and drift, with a flat country, and no outcrops of the older rocks.

A small outcrop of thin micaceous, blue sandstone and blue shale was found in a small run in the northeastern part of Richmond Township. This locality is near a small cemetery, and about one mile south of the east and west road leading east from North Richmond to Pennline, in the western part of Conneaut Township, Pennsylvania. This outcrop is in the Chagrin formation. A farmer stated that years ago by his house, which is just above this locality on the farm of L. A. Smith, he found coal. If any black rock was found it probably was from the eastern continuation of the Cleveland shale. Only pieces of bluish Chagrin shale, however, were seen in the material thrown out of the pit which he dug. Some of the arenaceous shales contain fossils.

The same north and south road crosses a run which is a tributary of the East Branch Ashtabula River from the west, about one-half mile south of the east and west road. In the run below the bridge, in 1910, blue, thin-bedded sandstones containing fossils had been washed out of the bed of the run.

Spirifer disjunctus Sowb. is the most abundant species; but there are also others, particularly *Strophalosia muricata* Hall and *Camarotœchia contracta* Hall. The fossilliferous blue sandstone is rather fine-grained, micaceous and splits into thin even layers. There are also bluish shales and bluish-gray harder sandstones. The outcrop is undoubtedly well toward the top of the Chagrin formation, since it is only about 1¼ miles southwest of the Berea sandstone as exposed at Pennline, Pennsylvania.

The complete list of fossils collected at this locality is as follows:

1. Spirifer disjunctus Sowb. .... (c)
2. Camarotœchia contracta Hall .... (rr)
3. Strophalosia muricata (Hall) Beecher .... (c)
4. Dalmanella tioga (Hall) Wms. var. elmira Wms. .... (r)
5. Pararca sao Hall (*?*) .... (rr)
   Broken along hinge line but markings are like those of this species.

In 1904 the Berea sandstone was shown in the highway gutter in Pennline, about two rods below and west of the four corners where the

Bates and Manning store is located. At that time a little more than 5 feet was shown by the roadside, the lower 3 feet or more of which is very soft, greenish-buff in color, and composed of moderately coarse quartz grains with some flat quartz pebbles. The upper part is in thinner layers and harder; but is a quartz sandstone with the lithologic characters of the Berea. The lower portion is soft and massive with the lithologic appearance of the Cussewago sandstone. In 1910, however, the gutter was so filled up and grassed over to such an extent that the sandstone scarcely showed and only loose pieces of the Berea were found.

On the north and south road through Pennline, however, and less than one-fourth mile south of the four corners, rocks were shown in 1910 by the east side of the highway. The upper outcrops were not far below the cemetery, near the brow of the hill, and not far above the house of Mr. E. B. Slack; but it is probable that later they will be more or less covered as the gutter fills up, particularly so far as the upper outcrops of coarse-grained sandstone are concerned.

Section South of Pennline, Pa.

No.		Thickness. Feet.	Total thickness. Feet.
3.	*Berea sandstone.* Outcrop of apparently very soft, much disintegrated Berea sandstone in road gutter near brow of hill. Rock composed of grains of quartz sand, much discolored, and cementing material all leached out. The sandstone also contains small white quartz pebbles. Between 3 and 4 feet is shown, some of which may have crept down the hill to some extent. Lithologic appearance and stratigraphic position of the *Cussewago sandstone*	4±	16
2.	Covered interval, opposite the house of E. B. Slack	8±	12
1.	Blue, thin-bedded sandstones alternating with shales. These sandstones are fossiliferous, containing not infrequent specimens of *Spirifer disjunctus* Sowb., and a few other species. The *Spirifer* is, however, the most abundant. In 1910 some 4 feet of these sandstones and shales were exposed between the house and the watering trough	4±	4

The complete list of species obtained in the sandstones of No. 1 of the above section is as follows:

1.	Spirifer disjunctus Sowb.	(c)
2.	Camarotœchia orbicularis Hall	(r)
3.	Strophalosia muricata (Hall) Beecher	(rr)
4.	Productella lachrymosa Con. var. lima Con. (?)	(rr)
5.	Chonetes setiger Hall	(r)
6.	Schuchertella chemungensis (Con.) Girty	(rr)
7.	Palæoneilo sp.	(r)
8.	Schizodus rhombeus Hall (?)	(rr)

It was reported to the writer that the wells on the ridge at the four corners in Pennline went through 15 feet of sandstone, which was harder as they drilled deeper in it, below which the slate was reached. It was also stated that on the hill to the west of the ridge as well as the one to the east no sandstone occurs. A large number of springs occur at the heads of the runs that rise about this ridge, which were running freely after the long drought of the summer of 1910, showing that there is a considerable supply of water feeding them.

This section is important and interesting since it shows that rocks like the Chagrin formation with its Chemung fauna of *Spirifer disjunctus* Sowb. extend nearly, if not quite, up to the Berea grit (Cussewago sandstone). This seems to show that the Bedford formation and Cleveland shale do not extend as far east as the Ohio-Pennsylvania State line. It seems to have been shown by the sections on Crooked Creek in the southern part of Trumbull Township, in Warner Hollow below Windsor Mills and on Mill Creek in the southern part of Windsor Township, that the Cleveland shale as followed eastward becomes thinner and probably eventually thins out and disappears. Perhaps the absence of the Bedford formation on the State line may be accounted for in a similar way. Again perhaps the finer grained sandstones and shales of the typical Bedford formation are gradually replaced, when followed eastward, by the coarser deposits which in Pennsylvania are known as the Cussewago sandstones and shales, although this does not appear to the writer as the explanation. Or they may have been deposited and then removed by erosion, leaving a disconformity between the Berea and Chagrin formations. In this bulletin numerous examples of disconformity between the Berea and Bedford in Ohio have been described; but in these examples only the *upper* part of the Bedford formation had been removed by erosion and not the entire formation. Another possible explanation of the disappearance of these two formations is that of overlap.

The banks of Peyton Run or North Shenango Creek, about one mile north of the east and west road from Pennline to Summit Station, are very sandy, and on the shallow side is a bed of sand which is used locally for plastering. It is not certain that this bed of sand is from the Cussewago, since it may possibly be a glacial instead of an alluvial deposit. The bed of sand in the run is apparently a deposit overlying one of gravel. The sand is composed of worn grains of white quartz which when examined under the microscope have the same size, shape and appearance as those of the Cussewago sandstone.

An exposure of very coarse-grained, greenish-buff (when damp) sandstone occurs in the highway gutter, one-eighth mile west of North Shenango Creek, on the first east and west highway south of the one passing through Conneaut Center. There is about 4 feet of the rock shown, which is very soft and friable and contains some flat disc-

shaped pebbles. Lithologically it agrees with the Cussewago sandstone.

One-fourth mile north of the above locality and just north of the house of L. G. Bollard on the highway and in the ravine at the same locality is shown coarse-grained, greenish-gray, friable sandstone, closely dotted with brown spots. It also contains some flat quartz pebbles. About 3 feet is shown by the roadside and about the same thickness in the bank of the stream west and above the highway.

These last two outcrops were described by Dr. White in his report on Conneaut Township, who gave their horizon as at the top of the Cussewago sandstone. In describing the first of them he wrote that "the top of the *Cussewago Sandstone* is seen exposed along the roadside, with the same character as near Summit Station, except that near its top are seen many pebbles of shale."[1] These two outcrops agree closely in lithologic appearance with others already described in Andover and Williamsfield townships, Ohio, which have been correlated with Dr. White's Cussewago sandstone of northwestern Pennsylvania.

A gully in the southeastern part of Conneaut Township, about 1½ miles north of Linesville and a similar distance south of Summit Station, just north of the house of Lisk & Son, affords an interesting section for this relatively flat country.

Section One and One-half Miles South of Summit Station.

No.		Thickness. Feet.	Total thickness Feet.
4.	*Orangeville shale.* Loose in bank, pieces of thin, black shale, fully as black as the Sunbury.		
3.	*Berea formation.* Highest outcrop shown in old quarry pits just above the road. This sandstone is tough, rather fine-grained, and only above its top are the black or blue shales of the Orangeville formation found. About 6 feet below the top of the quarry is a gray, moderately coarse-grained layer, which is probably the one formerly quarried to the greatest extent. At about the same distance below the top of the quarry, a rough and much iron-stained layer is shown in the roadside gutter. This portion of the Berea formation was called the *Corry sandstone* by Dr. White, and this is thought to be the locality where he stated that "About one and a half miles south from Summit Station the *Corry Sandstone* has been *quarried* to a small extent on the land of Mr. Daniel Spaulding; in irregular buff-colored flags 3″ to 6″ thick"[2]	6+	23−
2.	Below layer in highway and the quarry are rather buff, arenaceous shales. In bed of run, rather coarse-grained, greenish-buff (as wet) layers from 1 to 2 inches or more in thickness, one of which is at least 5 inches thick. Some of these layers are conspicuously ripple-		

[1]Second Geol. Surv., Pa., Q^4., p. 209.
[2]Ibid., p. 209.

No.		Thickness. Feet.	Total thickness. Feet.
	marked. From the 5-inch layer to the one at the base of the quarry is $16\frac{1}{2}$ feet by the level. The shales of this zone represent what Dr. White named the *Cussewago shales*	$16\frac{1}{2}$	$16\frac{1}{2}$
1.	Thin sandstones, alternating with shales, the sandstones rather finer grained and tougher than those in the superjacent zone.		

The Corry sandstone was named and described by Dr White in 1881 from quarries a mile south of and 300 feet higher than Corry, a city located in the extreme eastern part of Erie County, Pennsylvania, which it will be recalled is the northwestern county of that state. Dr. White thus described this sandstone: "A yellowish-white or buff-gray tint, and a compact fine-grained structure distinguish it from all the higher sandstones of the region" and further stated that it "is usually 10′ or 15′ thick I have nowhere seen it more than 30′."[1]

In the same volume Dr. White named and described the Cussewago shales, which he stated 'separate the *Corry sandstone* above from the *Cussewago sandstone* below, and hold (near the top) the *Cussewago limestone*. * * * *

"In some places the interval between the *Corry sandstone* and the *Cussewago sandstone* is filled, not with shales (with the limestone,) but with sandy flags (without the limestone;) * * *

"*The Bedford red shale formation* of Ohio, should in my opinion belong here, but I have seen no red shale. * * *

"The prevailing color of these shales is a bluish or ashen grey.

"Their average thickness is about 35′."[2]

These terranes are described by Dr White under the chapter entitled the "Oil Lake Group"; "Berea Grit of Ohio"; "Pithole Grit of Venango" and "Pocono Sandstone No. X, in part." In its opening paragraph he says "this group [Oil Lake] is composed of the *Corry* and *Cussewago sandstones* and the included *Cussewago limestone* and shale."[3] On the following page Dr. White said: "It certainly looks as if the *Waverly Conglomerate* of these sections [in Richland, Ashland and Cuyahoga counties, Ohio], the *Berea Grit* of Ohio, and my *Oil Lake group* in Crawford and Erie counties, occupied the same horizon."

It is evident from the description of sections in this bulletin extending from Cuyahoga County, Ohio, into Crawford County, Pennsylvania, that Dr. White was perfectly correct if he intended to correlate the *entire* Oil Lake group of Pennsylvania with the Berea formation of Ohio. This interpretation is supported by Dr. White's language in another part of the report when discussing Read's section in Vernon Township, Ohio,

[1]Ibid., p. 93.
[2]Ibid., pp. 94, 95.
[3]Ibid., p. 91.

he stated that "we must look 100' lower [than Read's horizon] for the genuine Berea, viz: in the *Corry and Cussewago sandstones* of the Oil Lake group (the *Pithole grit* of the Oil regions)."[1]

It is not clear, however, that such was Dr. White's exact meaning, since under his description of the Corry sandstone it was stated that "near the northwest corner of N. Shenango township its outcrop passes into Ohio and continues west as Dr. Newberry's *Berea Grit* outcrop."[2] Following which statement is the further one that "the rock of the East Cleveland quarries looks very like the Corry rock."[3] Apparently Professor Cushing concluded that it was only the Corry sandstone which was correlated with the Berea, since he stated that as a result of his own studies in northeastern Ohio "the work so far done would seem to show that Professor White is right in his claim that the Corry sandstone is the equivalent of the Berea;"[4] while Professor Stevenson wrote that the Berea grit is "evidently the same with the upper part of White's Oil Lake group."[5]

Dr. White was mistaken if he considered the Waverly conglomerate of Ohio (Black Hand and probably also including the lower part of the Logan formation) the same as the Berea, since it occurs at a higher horizon, nearer that of the Shenango sandstone of the Pennsylvania section. It is also probably incorrect to correlate the Cussewago shale with the Bedford shales which lie *below* the base of the Berea formation in Ohio. Dr. White in his interpretation of Dr. Newberry's Cleveland section correlated with a (?) mark the Berea grit with the Corry sandstone and in the same way the blue sandstone of the Bedford (Euclid lentil) with the Cussewago sandstone.[6] There is nothing, however, in common between these sandstones. The Euclid lentil is a fine-grained, compact sandstone instead of a coarse-grained and very friable one. Then stratigraphically the Euclid thins out and disappears as the Bedford is followed eastward; while the shaly sandstones and shales of the Berea, called the Cussewago shales in western Pennsylvania, develop at that horizon in the Berea formation in eastern Ohio and may be followed from this State to their typical locality in Pennsylvania.

Dr. Orton in his later work correlated the Berea grit with the Corry sandstone of Dr. White, since he wrote that "his [White's] Corry sandstone appears to be none other than the Berea grit."[7]

Dr. George H. Girty has devoted much time to field and laboratory study of the Waverly and in 1901 is reported as saying that "the Berea grit of the Waverly group was found to be the equivalent of the Cussewago

[1]Ibid., pp. 85, 86.
[2]Ibid., pp. 93,94.
[3]Ibid, p. 94 f. n. Also see interpretation of Dr. Newberry's Cleveland section on p. 92 and Fig. 11b of p. 82.
[4]Proc. Am. Assoc. Adv. Sci., Vol. XXXVI, 1888, p. 215.
[5]Bull. Geol. Soc. America, Vol. XIV, 1903, p. 41.
[6]Second Geol. Surv. Pa., Q^4, p. 92 and see section 11b on p. 82.
[7]Geol. Surv. Ohio, Vol. VII, 1893, p. 33.

sandstone of northwestern Pennsylvania."[1] Later, however, he stated that "the Berea grit of Ohio is White's Cussewago sandstone, together with probably the Cussewago flags and Corry sandstone."[2] Finally, Professor Schuchert in his "Table of Mississippic Formations" put the Berea grit at the base of the Pocono, which he correlated as follows with the formations of northwestern Pennsylvania: "Berea (Cussewago and Corry of Pennsylvania)."[3]

The results obtained in this bulletin seem to show conclusively that the Berea formation of Ohio is the western equivalent of the sandstone of western Crawford County, Pennsylvania, identified by Dr. White as the Corry sandstone and the subjacent Cussewago shales and Cussewago sandstone.

An interesting exposure of the Cussewago sandstone was studied by the roadside on the Reuben and Charles Reece farms to the southeast of Summit Station. It is shown in the gutter on the north and south road parallel to the Erie and Pittsburgh Railroad, where about 10 feet was measured. It is rather buff in color, coarse-grained, very friable and has been very thoroughly leached of its cementing material. The layers are, however, distinctly shown so that there is no question about its being a bedded sandstone. The upper layers are apparently coarser than the lower ones. At this location in flat loose blocks (but not transported) numerous fossils were seen. The writer is not certain, however, that they were from the Cussewago shales; perhaps they were from a higher horizon. The box containing them was lost by the railroad in transportation.

This is the locality which was described as follows by Dr. White in the Conneaut Township report:

"Just south from Summit Station the *Cussewago Sandstone* is seen along the road which passes north and south parallel to the E. and P. Railroad. It possesses the same loose incoherent texture here as so often elsewhere; at first sight I mistook its outcrop for a heap of *Drift sand;* for marks of the spade were left where it had been shoveled for making lime mortar. On closer examination shales and harder layers of sandstone, regularly stratified, were found on top of it. The sand has a greenish hue, and contains a considerable quantity of smoothly worn pebbles of quartz, mostly flat in shape.

"Only 6′ to 8′ of the top of this curious deposit could be seen."[4]

Summer Hill Township, Pa.—Summer Hill Township, Crawford County, lies to the east of the northern half of Conneaut Township.

The old D. V. Miller quarry, which was worked in 1836–40 to furnish stone for the canal locks, was visited. It is now on the farm

[1]Science, N. S., Vol. XIII, April 26, p. 664.
[2]Proc. Washington Acad. Sci., Vol. VII, 1905, p. 6.
[3]Bull. Geol. Soc. America, Vol. XX, 1910, p. 548.
[4]Second Geol. Surv. Pa., Q^4, p. 209.

of John S. Andre and is overgrown with grass and trees. Loose blocks of stone, however, which apparently came from it are buff in color, and like the stone later to be described in the Montgomery quarry located three miles to the north.

Farther up the run is a shale bank of about 10 feet which resembles the Orangeville. The contact is not shown and apparently the outcrop of shale is somewhat above the base of that formation. These soft bluish-gray shales in the run contain rather numerous specimens of *Lingula melie* Hall. The size and proportions of these specimens agree fairly well with those of various sizes from the typical locality for this species at Chagrin Falls, Ohio. The measurements of 4 specimens are as follows:

Length	Width
11.5 mm.	8 mm.
8 "	5 "
7.25 "	4.5 "
7 "	4.5 "

The fauna and lithologic appearance of these shales are similar to those of the Orangeville as shown at their typical locality in that village. The east highway on which Dr. White reported the Orangeville shale is a little above this locality. He also described the neighboring Miller quarry, which he referred to the Corry sandstone, gave the thickness as from 10 to 12 feet, and stated that its "aspect [is] much the same as at Montgomery's, except that there is more interstratified shale."[1]

The old J. R. Montgomery quarry is located on his farm to the east of Carr's corners, two miles southeast of Conneautville and 300 feet higher than the power house in that village. The quarry at the time of the writer's visit was filled with water. In a small run above it 5 ± feet of bluish shales interstratified with layers of bluish-gray, micaceous, fairly fine-grained sandstones are shown which do not resemble the Orangeville shales. A little farther down the run is a small outcrop of the quarry stone which is of a buff color, rather fine-grained, somewhat friable and with something of the texture of the ordinary Berea sandstone. Mr. Montgomery said that some of the stone from his quarry would have made grindstones.

This is the quarry in the Corry sandstone described by Dr. White from which, he wrote, "a considerable amount of building stone has been taken * * * thickness, 8′; upper 5′ only quarried. The rock has its characteristic fine grained and buffish white color; and the layers vary from 6″ to 12″, occasionally thickening up to 3′."[2]

A ledge is shown in an old quarry on the highway and in the first gully south of the J. R. Montgomery house, on the farm of Rev. Alli-

[1]Ibid., p. 207.
[2]Loc. cit.

son (?). Mr. Montgomery said that this ledge is the same as the one quarried below his house and the elevation, which the barometer gave as the same, apparently confirms this statement. The top of the sandstone is rather rough, the rock shaly and much iron-stained as in many outcrops of the top of the Berea sandstone in Ohio. The best exposure is on the northern bank, and in a small run 10 feet of shale immediately overlying the sandstone is shown. At the contact of the shale and sandstone there is a very soft drab layer, almost a clay, about 6 inches thick, with some black or blackish streaks. Above this layer the shale is drab with blackish layers in which are fossils as *Lingula melie* Hall. The specimens of *Lingula* are rather infrequent and fairly small; but have about the usual proportions of length to breadth of *L. melie* Hall. One specimen that was measured is 6.25 mm. long and 4 mm. wide. The upper part of the bank is composed of black or blackish shale, weathering to a brownish color. All this shale agrees closely with the lower part of the Orangeville, which it undoubtedly is. The sandstone and the black and drab shales are shown in the highway gutter to the north of the quarry. Some of the shale as weathered has split into very thin flakes and is decidedly black in color. The sandstone below the shale as examined downward soon changes to a bluish rather coarse shale, alternating with thin sandstones, and about 3 feet is shown. This zone is similar to the shale shown above the J. R. Montgomery quarry.

Barometrically 55 feet lower in this gully is the top of a rather coarse-grained decidedly bluish sandstone which is very friable and is the Cussewago. Above the top of this sandstone is a fairly steep bank the lower 10 feet of which is covered; but the upper 13 feet or more is exposed. This upper part is composed mainly of a rather coarse, sandy micaceous buff and bluish shale which is lithologically not at all similar to the Orangeville shale and belongs to the Cussewago. The following section has been constructed from the outcrops at this locality:

Section South of the J. R. Montgomery House.

No.		Thickness. Feet.	Total thickness. Feet.
6.	*Orangeville shale.* Upper part of bank black to blackish shale, weathering to a brown color. Lower the shale is drab in color, with blackish layers in which *Lingula melie* Hall occurs. At the base a drab, very soft layer with black streaks about 6 inches thick	10	65
5.	*Berea formation.* The top of the sandstone is rough and much iron-stained and soon changes to a bluish, coarse shale, alternating with sandstones. Thicker layers of rather fine-grained sandstone formerly quarried; but thickness not determined. *Corry sandstone*	3±	55
4.	Mainly covered zone	29	52

No.		Thickness. Feet.	Total thickness. Feet.
3.	Rather coarse, sandy, micaceous, buff and bluish shale. *Cussewago shale*	13	23
2.	Covered zone	10	10
1.	Bluish, rather coarse-grained sandstone, which is rather friable as found on the bank of the run. Only upper part of zone exposed. *Cussewago sandstone.*		

The Orangeville shale was also reported from this immediate vicinity by Dr. White, who wrote that "along the road where a cutting was made, just south from this [the J. R. Montgomery quarry], and 60′ higher, 20′ of blue *Orangeville shale* is seen, filled with *Linguloe.*"[1]

On the Mary A. Crate farm the upper three layers of the blue Cussewago sandstone are shown at about the same elevation as in the gully described above. The top one is a foot in thickness, the middle 1½ feet and the bottom one 2 feet, the base of which is at the bottom of the excavation. According to Mr. Crate this stone hardens on seasoning, and he pointed out blocks of it used in the steps and cellar wall of his house which were rather hard. Other blocks which he said came from this quarry and have been exposed to the weather for many years are decidedly hard. If his statements be correct then this stone may be valuable for building purposes when quarried and seasoned in the summer sun before using.

Hayfield Township, Pa.—To the east of Summer Hill and Summit townships, is Hayfield Township, crossed by Cussewago Creek, which enters French Creek in Vernon, the next township to the south, opposite the city of Meadville. Cussewago Creek Valley is bordered by fairly steep hills, and the streams descending from the higher ground in some instances afford opportunity for studying the Carboniferous formations.

A stream crossing the valley road near the brick house of Mr. P. W. Boyer, about one mile south of Hayfield or Little's Corners, affords excellent outcrops of some of the terranes as they are shown in the glen above the highway. This is the locality of the "Section below Hayfield" described by Dr. White.[2]

Section of Boyer Glen about One Mile South of Hayfield.

No.		Thickness. Feet.	Total thickness Feet
9.	*Sharpsville upper sandstone.* Highest outcrops near head of stream by farm-house. Bluish-gray, fine-grained sandstone, slightly friable, and not rough to the touch. There are numerous fucoidal markings on the sandstones, and the lithology and general appear-		

[1]Ibid., p. 207.
[2]Ibid., pp. 201,202.

No.		Thickness. Feet.	Total thickness. Feet.
	ance are very similar to those of sandstones in northern Ohio, that are referred to the Sharpsville sandstone in this bulletin. These sandstones are described as flaggy in Dr. White's section, and given a thickness of 25 feet	29	270
8.	*Meadville lower limestone.* A massive, bluish-gray, compact limestone about 15 inches thick, given as 2 feet in Dr. White's section, as shown in ledge on stream bank. Dr. White wrote that "The *Meadville Lower Limestone* (rather flinty and with glassy fracture) is finely exposed and its peculiar round blocks are scattered along the ravine from its head to its mouth."[1]	$1\frac{1}{4}$	241+
7.	*Sharpsville lower sandstone.* These sandstones are rather flaggy, and in the lower part alternate with shales, which predominate in thickness in this part of the terrane. A fairly heavy layer, however, occurs at the horizon that was selected for the base of these sandstones. Described as flaggy in Dr. White's section, with a thickness of 10 feet, and a 6-inch layer of limestone at the base. It is stated that "*The Sharpsville Sandstone,* upper and lower, are more massive here than usual; bluish-white, fine-grained, layers 1′ to 2′ thick, with very little interstratified shale."[2]	20	240
6.	*Orangeville formation.* Bluish shales predominate; but there are frequent lenticular or thin layers of sandstone. The shales in part are somewhat arenaceous; but at least part of them are very argillaceous, of blue color, and carry specimens of Lingulas to the very top, as stated by Dr. White	77	220
5.	A flaggy sandstone layer 3 feet thick according to Dr. White, which is conspicuous in the bank of the stream, where it is rather massive, and makes a small fall	3	143
4.	Bluish, argillaceous shales, containing Lingulas. Contact with lower formation not shown. This glen is a fine locality in which to study the Orangeville formation, with the exception of its extreme lower part. This section gives a thickness of at least 90 feet for the Orangeville formation, while another reading of the barometer gave 85 feet for the same interval. On Dr. White's section, the thickness of this same exposed part of the formation is given as 88 feet. He also reported that "The *Orangeville shale* as a mass is thicker here than usual along French creek. It is filled from top to bottom with *Lingulae* and *Discinae;* but I saw no other shells. The shales have a dark bluish color throughout, and are quite soft."[3]	10	140
3.	Covered interval	15	130
2.	*Berea formation.* Bluish, coarse-grained, flaggy and		

[1]Ibid., p. 202.
[2]Ibid., p. 202.
[3]Ibid., p. 202.

No.		Thickness. Feet.	Total thickness. Feet.
	friable sandstone in bed of stream; but not much shown. Most of this interval covered. Sandstone shown in bed of stream, 55 feet below the top of this zone	55	115
1.	Concealed interval to fossiliferous sandstone in bed of stream near the house of Mr. P. W. Boyer. Lowest rocks exposed on stream	60	60

The Orangeville shale of the above section contains numerous medium sized specimens of *Lingula melie* Hall. One of these measures 7 mm. in length and 4.5 mm. in width. Some of the other specimens agree in proportion of length to breadth better with those given by Hall for *L. cuyahoga*; but they are smaller in size. One of these is 10 mm. long and 6 mm. wide, which is the exact proportion of 5 to 3 that is given by Hall for *L. cuyahoga*. At present, however, these specimens are not separated from *L. melie*, because the type specimen of *L. cuyahoga* is a considerably larger form with a length of 15 mm. and a width of 10 mm., which also gives the proportion of 3 to 2, or those of *L. melie* according to Professor Hall. There is some variation in the proportion of length to breadth of the specimens that have been listed by the writer as *L. melie* Hall; but if they agree fairly well with the size of the type specimens of this species they have not been separated from it.

Dr. White's Bartholomew's section on the Bartholomew farm (Hunter in 1904) on a run about one mile northwest of Hayfield was examined. The light blue, soft Cussewago sandstone as described by Dr. White was readily found. One layer in the bed of the stream shows fairly well formed ripple-marks. Buff colored rather fine-grained and somewhat friable sandstones occur 35 feet higher, which in texture are like similar fine-grained sandstones of the Berea in Ohio. Five feet higher at the roadside are thinner bedded sandstones with a rough surface, where it looks as though the upper rough layer of the Berea formation is thinning out as it is followed eastward and the shales below are thin and bluish. It is believed that this upper rough surface corresponds to the rough top of the Berea sandstone in Ohio. These upper sandstones at this locality are evidently what Dr. White called the Corry sandstone in this section, with a thickness of 10 feet, which he described as having "been quarried here for buildings in the surrounding country; in layers 6″ to 18″ thick, tolerably fine-grained, grayish-white, with a tinge of yellow."[1] Ten feet of the lower sandstone was also reported as visible, concerning which Dr. White wrote as follows: "The *Cussewago sandstone* makes the bed of the stream; its top is quite hard for two feet; but below that the sand becomes coarse and coheres

[1]Ibid., p. 204.

so loosely that one can remove it almost as easily as from a heap of silt-sand along any stream. The color is a greenish-brown but occasionally *black*."[1]

The Canal Feeder dam section in the southeastern part of the township, which was described by Dr. White, was also studied. At this locality, which is known as Bemistown, a run enters French Creek from the west some 2½ miles northwest of Meadville. The rocks of this section were examined somewhat hastily, the highest ones of which are shown in the edge of the pasture above the woods.

Section of Bemistown Run.

No.		Thickness Feet.	Total thickness. Feet.
4.	The highest outcrops in this section were called the *Corry sandstone* by Dr. White, and the thickness given as 5 feet. This sandstone is blue, rather fine-grained, and lithologically resembles more closely the Cuyahoga sandstones than the top of the Berea	5	160
3.	Bluish-black, argillaceous shale, which is very compact, and contains numerous specimens of Lingulas at a horizon 10 feet or more below the base of the sandstone. Near the base of this zone is a 2-inch sandstone, below which are about 3 feet of blue, somewhat sandy shales. The color of this shale and its fauna raises the question whether it may not be the Orangeville	30±	155
2.	Blue, rather fine-grained sandstone, the top surface of which is rough and irregular and more like the top of the Berea than the upper sandstone. The lower part of this zone is a thin-bedded, gray, friable sandstone, composed of rather coarse grains of quartz. Perhaps the color is slightly greenish-gray when wet, as exposed in the bed of the run. This lower part is the sandstone that Dr. White called the *Cussewago,* and described as massive, with a thickness of 27 feet. The barometer gave 50 feet thickness for the interval from the base of the shale to the base of the Cussewago sandstone, and in Dr. White's section, the Cussewago and flaggy sandstone above, which correspond to this sandstone, have a combined thickness of 47 feet	50	125
1.	Fine-grained, blue, flaggy sandstones, with some shale. At a horizon between 10 and 15 feet below the base of the Cussewago sandstone collected specimens of *Spirifer disjunctus* Sowb., and some other poorly preserved fossils. A very fossiliferous layer of shaly sandstone occurs 20 feet or more below the base of the Cussewago, which contains numerous specimens of *Spirifer disjunctus* Sowb., and much less abundantly specimens of *Reticularia præmatura* (Hall), *Euomphalus hecale* Hall (?), *Pterinea* sp. and a few others. Farther down the run, a good many of the thin-bedded,		

[1]Loc. cit.

No.		Thickness. Feet.	Total thickness. Feet.
	blue sandstones are ripple-marked. Fossils were collected at various horizons in the lower part of the glen. These blue, thin-bedded sandstones and shales were studied down to the lowest outcrops above the highway, which the barometer gave as between 50 and 80 feet below the base of the Cussewago sandstone. The barometer was falling when the second readings were taken, which gave 50 feet, and probably Dr. White's thickness of 75 feet, for apparently the same interval, is essentially correct	75±	75

The above section clearly shows the presence of *Spirifer disjunctus* Sowb. or a form so similar to it that it is practically impossible to separate them within 10 or 15 feet of the base of the Cussewago sandstone, while the same species occurs commonly in association with other Devonian species only some 20 feet below the base of this sandstone. These fossiliferous shales and sandstones belong in what Dr. White named the Riceville shale, and this is the one detailed section which he gave in the chapter devoted to the description of that shale.[1]

From the outcrops 20 feet below the base of the Cussewago sandstone the following species were collected:

1. Spirifer disjunctus Sowb. (c)
2. Reticularia præmatura (Hall) Schuchert (rr)
3. Euomphalus (Straparollus) hecale Hall (c)

From the lower part of the section the following species were obtained:

1. Spirifer disjunctus Sowb. (c)
2. Camarotœchia orbicularis Hall (rr)
3. Reticularia præmatura (Hall) Schuchert (a)
4. Schuchertella chemungensis (Con.) (rr)
5. Strophalosia truncata (Hall) Beecher (?) (rr)
6. Productella lachrymosa Con. var. lima Con. (?) (rr)
7. Productella hirsuta Hall (?) (r)
8. Chonetes setiger Hall (c)
9. Euomphalus (Straparollus) hecale Hall (rr)
10. Limoptera sp. (rr)

The outcrops in this township in the hills bordering Cussewago and French creeks are important, since the typical outcrops for Dr. White's Cussewago sandstone are located in the southern part of the township on a tributary of French Creek. The sandstone at this locality was described by Dr. White as "a very coarse, dark, grayish-brown rock,

[1]Second Geol. Suvey Pa., Q^4, p. 97.

the grains of which cohere loosely, and rapidly crumble apart on exposure."[1]

The Meadville limestones are also named from outcrops in the vicinity of Meadville, only about 3 miles southeast of the southern boundary of Hayfield Township. The Meadville lower limestone was described in general by Dr. White as a "thin bed of impure limestone. * * *

"Seldom more than 2′ thick, and often only 1′, it is nevertheless so persistent, that I found it in every part of Crawford county; afterwards in Mercer county, along the Shenango valley, for 21 miles to where near Sharon it goes beneath water level. * * *

"*This limestone* is very hard and flinty * * * 'It lies', says J. T. Hodge, who first described it, 'in large and nearly square masses, the angles of which are more or less rounded off, showing the readiness with which the lime is dissolved out of the rock. By the removal of this ingredient, and the oxidation of the iron in the stratum, it acquires a brown siliceous crust, sometimes thick'."[2] Finally, under the description of the typical outcrops in Mead Township, in which the city of Meadville is located, Dr. White reported the Meadville lower limestone finely exposed in the bed of a stream to the northeast of the city where "large, angular blocks (with the edges rounded off) lie scattered along the bed of the stream for a considerable distance near the hydraulic ram which supplies the cemetery with water. The limestone rock is quite hard, and breaks with the peculiar glassy fracture so common to the calcareo-siliceous deposits under the Conglomerate."[3]

It is also important to note that the blue shales and flaggy sandstones below the Cussewago sandstone in Hayfield and Mead townships carry Chemung fossils, among which is the very characteristic species of *Spirifer disjunctus* Sowerby. Dr. White reported "hundreds of specimens of *Productus Boydii*, and *Spirifera disjuncta* [*Spirifer disjunctus*], besides a small *Orthoceras*"[4] in the blue shale below the Cussewago sandstone in Hayfield Township. Also in the bed of Mill Run, within the limits of the city of Meadville, it is stated that "the thin flaggy rocks are filled with fossils, among which were seen *Aviculopecten suborbicularis*, *Spirifera disjuncta*, *Productella Boydii*, and many *encrinal stems* and fragments."[5] The diagnostic character of *Spirifer disjunctus* for the Chemung formation as pointed out by Prof. Henry S. Williams and other geologists, has already been dwelt upon in this bulletin. It is intended here simply to call attention to the fact that these *Spirifer disjunctus* bearing rocks in Meadville and its vicinity also contain certain other species which the writer has collected in the upper part of the

[1]Ibid p. 201.
[2]Ibid., pp. 87,88.
[3]Ibid., p. 169.
[4]Ibid., p. 201.
[5]Ibid., p. 171.

Chagrin formation in northern Ohio in association with *Spirifer disjunctus*. Some of the species occurring in these shales near Meadville and in the upper Chagrin of northern Ohio are *Cyrtia alta* Hall, *Reticularia præmatura* (Hall) Schuchert and *Strophalosia muricata* (Hall) Beecher.

Meadville, Pa., Sections.—Mill Run flows through the southern part of Meadville and enters French Creek. The run was followed from the Grove Street bridge for a mile or more to the east, along which for some distance are banks where sandstones and shales outcrop. The bed of the main stream, however, does not rise very rapidly, and it is not very good for a section. The exposed rocks are all blue, fine-grained and mostly thin-bedded sandstones alternating with shales. Many blocks were seen containing specimens of *Spirifer disjunctus* Sowb. and in addition specimens of *Productella, Chonetes* and Pelecypods. Tributaries entering this run from the hills bordering it give sections of the higher rocks of Mississippian age, as for example the Ellis Mill Run section described by Dr. White, that begins with the Orangeville shale and continues up to the Shenango sandstone, which has a thickness at this locality of 20 feet.[1]

From the outcrops on Mill Run above the Grove Street bridge the following species were collected:

1. Spirifer disjunctus Sowb. .... (c)
2. Chonetes setiger Hall .... (r)
3. Productella boydi Hall (?) .... (rr)
4. Strophalosia muricata (Hall) Beecher (?) .... (rr)
5. Camarotœchia orbicularis Hall .... (rr)
6. Sphenotus clavulus Hall (?) .... (rr)
   Only anterior part preserved.
7. Glossites patulus Hall (?) .... (rr)
   The specimen certainly has the appearance of this species. It is 35 mm. long and 21 mm. high, while in Hall's description one specimen is given as 36 mm. long and 21 mm. high.

A run in Vernon Township, opposite the lower part of Meadville, enters French Creek above the Lower Iron Bridge or Kerrtown Bridge and below the Meadville Brewing Co.'s plant. The section on this run was described by Dr. White, the lower rocks of which he said contained many species of Chemung shells while it extended up to the Corry sandstone.[2] The Cussewago and Corry sandstones were not seen, and although the course of the run was not followed much above the reported horizon of the Cussewago sandstone it looks at present as though the older rocks in the upper part of the stream are mostly covered.

[1]Ibid., p. 169.
[2]Ibid., pp. 164, 165.

Section Opposite Meadville.

No.		Thickness. Feet.	Total thickness. Feet.
3.	Thin layers of blue sandstone and shales on bank of run, which is the highest outcrop seen. Above this point the rocks are apparently mostly covered. This interval is partly covered, at the base of which is the old dam	30	140
2.	Blue, thin-bedded sandstones and shales, which are largely arenaceous, continue all the way down to the lowest outcrops studied on this run. Certain layers in this entire interval contain numerous specimens of *Spirifer disjunctus* Sowb., associated with other species which are much less abundant. Near the base of this zone a blue sandstone crosses the stream, and contains many specimens of *Spirifer disjunctus* Sowb., together with others of *Reticularia præmatura* (Hall) Schuchert, *Camarotœchia orbicularis* Hall, *Productella* sp., *Euomphalus hecale* Hall and two or three species of Pelecypods. The lithologic appearance of these rocks is certainly very similar to much of the Chemung formation in New York	75	110
1.	Mostly covered interval to level of French Creek	35	35

This section was measured by the barometer, which gave the highest outcrops seen as 140 feet higher than French Creek. In Dr. White's section the base of the Cussewago sandstone is given as 140 feet higher than French Creek, and since the run was followed for some distance above the highest outcrops seen, it is believed that White's horizon for the Cussewago sandstone was reached. The greater part of the rocks studied apparently correspond to the Riceville shale of Dr. White's classification. The lower part of the section he referred to the "Venango First oil sand" with a (?), and the writer is not certain whether the lower sandstone in which he found the most fossils is in this horizon or above it.

From the lower part of zone No. 2 of the above section the following species were collected:

1. Spirifer disjunctus Sowb. .... (a)
2. Camarotœchia orbicularis Hall .... (r)
3. Reticularia præmatura (Hall) Schuchert .... (r)
4. Productella lachrymosa Con. var. lima Con. .... (rr)
   Dr. White listed *P. boydi* at this locality; but this specimen agrees better with the species listed above.
5. Chonetes scitulus Hall........ (c)
   Poorly preserved specimens.
6. Euomphalus (Straparollus) hecale Hall........ (r)
7. Schizodus chemungensis Con. var. quadrangularis Hall........ (r)
   The umbonal slope is not so sharply angular as in the figures of this variety; but the proportions, length 38 mm. and height

33 mm., agree with a specimen described by Hall which is 38.5 mm. long and 33 mm. high.

8. Sphenotus clavulus Hall (?) ---------- (rr)
9. Pararca neglecta Hall (?) ---------- (rr)
10. Loxonema sp. ---------- (rr)

These sections show conclusively that in the vicinity of Meadville *Spirifer disjunctus* Sowb. extends up nearly to the base of the Cussewago sandstone. It was found within about 12 feet of the base of the Cussewago in the Bemistown section. In addition, specimens of *Reticularia præmatura* (Hall) Schuchert, *Strophalosia muricata* (Hall) Beecher, *Camarotœchia orbicularis* Hall, *Productella* sp., and other species are found in this terrane, although perhaps not continuing to so high an horizon as *Spirifer disjunctus*. The rocks apparently correspond to the upper part of the Chagrin formation in northeastern Ohio, and contain a similar fauna.

Well Records in Spring and Beaver Townships, Pa.—Directly north of Summit Hill Township is Spring Township, to the west of which is Beaver, which borders the Ohio line, and is directly north of Conneaut Township, Crawford County, Pennsylvania. The western part of Spring Township and all but the southern portion of Beaver are covered by younger rocks than those which have just been considered in the neighboring townships of Crawford County. Several wells have been drilled to a considerable depth in these townships, and the partial records obtained of them are deemed of sufficient importance to warrant their publication.

Conneautville is located in Conneaut Creek Valley on the southern line of Spring Township. In 1888 a fairly deep well was drilled in the vicinity of this village, in which at a depth of 2,667 feet mineral water was obtained in abundance, so that it is known as the Bittern well. The mouth of the well is located 3,200 feet north of east of the Power House and 85 feet higher than the level of the square in front of this hotel, which makes its elevation above sea level about 1,030 feet. In a small run near the well are bluish-gray sandstones and shales, which are fossiliferous, and probably belong in the Venango oil sand group of Dr. White. It may be stated that immediately beneath the Cussewago sandstone Dr. White gave the Riceville shales with a thickness of 80 feet, directly beneath which is the Venango oil sand group. The Venango upper sand according to Dr. White contains *Spirifer disjunctus* and other fossils which he "considered good Chemung types."[1] *Spirifer disjunctus* has been used by Prof. Henry S. Williams to designate the fauna of the Chemung formation[2] and recently he has stated that "*Spirifer disjunctus* has been generally regarded as one of the most characteristic

[1]Ibid., p. 102.
[2]Bull. U. S. Geol. Survey, No. 210, 1903, pp. 50, 83.

Chemung species."[1] Professor Schuchert lists this species as only from the Chemung,[2] while numerous other geologists consider it as characteristic of the Chemung formation, so that it appears fairly safe to correlate these rocks with the New York Chemung.

It must be remembered, however, that Dr. John M. Clarke reports *Spirifer disjunctus* above the Wolf Creek conglomerate,[3] a lentil in the Cattaraugus beds of southwestern New York, which he considered the basal stage of the Paleocarbonic of that State.[4] Mr. Charles Butts in his article on the "Fossil faunas of the Olean [New York] quadrangle" lists *Spirifer disjunctus* from the Cattaraugus formation, which he puts in the Devono-Carbonic,[5] and also from the superjacent Oswayo formation which he called Subcarbonic.[6] Finally, Dr. Clarke in discussing the "Construction of the Olean rock section," and in support of "placing the dividing line between the Devonian and Carboniferous at the base of the Cattaraugus beds," wrote as follows: "It matters little if among the superstitial species one remains so characteristic everywhere of the later Devonic as Spirifer disjunctus, for not alone in New York does this species transcend the limit of the Devonic and enter the Carbonic."[7]

The Cattaraugus beds are given as the basal formation of the Mississippian group of the Carbonic system by Mr. C. A. Hartnagel in the last edition of Handbook 19 of the New York State Museum.[8]

The Venango oil sand group is mapped as extending $1\frac{1}{2}$ miles on each side of Conneaut Creek at Conneautville, so that it appears safe to state that the Bittern well began in the Venango oil sand group, which is of Chemung age. A partial set of samples of the drillings was saved by Mr. Wm. A. Hammon, of Conneautville, which he kindly permitted the writer to study. Samples from this well were also studied by Prof. Charles F. Mabery, of Case School of Applied Science, who gave particular attention to the mineral water obtained from the bottom of this well. The following record is based upon the samples examined by the writer together with some information furnished by Mr. Hammon.

Record of Conneautville Bittern Well

Depth. Feet.	Description of Sample.
	Light shale.
350.	Light gas vein and lower oil and gas.
525.	Heavy gas vein.
750.	Dark shale.

[1]Ibid., Folio 169, Field Edition, 1909, p. 81.
[2]Ibid., No. 87, 1897, p. 387.
[3]N. Y. State Mus., Bull. 52, 1902, p. 526.
[4]Ibid., Handbook 19, 1903, p. 8. In the April, 1912, edition see Table I and p. 87.
[5]Ibid., Bull. 69, 1903, pp. 993, 994.
[6]Ibid., pp. 994, 995.
[7]Ibid., p. 999.
[8]Loc. cit., April 1912, Table I and p. 87.

Depth. Feet.	Description of Sample.
1150–1340.	Very dark shale.
1350.	Very dark gray to black shale. Some of the chips are rather black, but have white streak. Hard, gritty shale. (First sample examined by writer.)
1500–1640.	Reported as dark shale.
1715.	Sample a mixture of greenish and blackish shale. Some of the chips have a brownish streak.
1900–2052.	Reported as dark shale.
2052–2200.	Reported as first sand.
2500.	Reported as black slate.
2337.	Sample composed entirely of black shale, which is hard and gritty, with decidedly brownish streak. *Marcellus shale.*
2352 and 2357.	Light gray limestone, which effervesces strongly in cold HCl. Mr. Hammon thinks traces of limestone were noted at 2340. *Onondaga limestone.*
2395.	Somewhat darker gray limestone, effervescing strongly in cold HCl, which contains small fossils. Drillers reported Trenton rock at 2365 feet.
2420–2430.	Sample of dark gray, compact limestone, which effervesces strongly in cold HCl. At 2435 drillers reported Trenton rock with shells.
2500.	Sample composed of very dark gray to almost blackish limestone, which effervesces strongly in cold HCl. (This on Professor Mabery's diagram is called a "Sand rock"; but it is clearly a limestone, only somewhat hard.)
2667.	Reported as very white sand with bittern water.

The following account of this well which was published by Professor Mabery, was given to the writer by Mr. Hammon.

"In the study of mineral waters, I have given particular attention to the water from a deep well at Conneautville, Pa.

"While drilling a test well for oil or gas, this brine was struck at a depth of 2,667 feet. The water apparently shot up with great force, sufficient to raise the drilling tools a considerable distance and prevent any further drilling. The water rose to a height of about 1,800 feet in the well and at that point the level remained practically unchanged, notwithstanding the efforts made to exhaust it by pumping.

"Although the oil sands were below this; but very little oil was found and this at a depth of 350 feet where a light vein of gas was also struck. From this point to 525 feet there were traces of oil and gas. At 525 feet a much heavier vein of gas was reached, but the oil had almost entirely disappeared. From 525 to 750 feet the drill passed through a dark slate. Then a very dark shale was reached, which continued until 1,340 feet, when a dark slate in granular form made its appearance continuing to 1,640 feet. From 1,640 to 2,052 dark slate and shale. At 2,200 the first sand was reached and at 2,300 a black slate. At 2,365 Trenton rock was struck, which, at 2,392 feet, became very hard

and close [grained]. For the next 48 feet drilling was through solid rock containing shells. At 2,435 sand rock was struck which continued to 2,500, where a very white sand was reached. This sand continued until the bittern water was struck at a depth of 2,667 feet."

The geological part of the above account is not altogether reliable, for, as has been already stated, an examination of the sample from a depth of 2,500 feet showed it to consist of limestone chips instead of a "very white sand." At a depth of 2,352 feet, or thereabouts, a thick limestone was reached which is the Onondaga of New York. The statement that Trenton rock was reached at 2,365 feet is obviously an error, and one that is frequently made by drillers and others in their reports of wells beginning in the upper or middle Devonian. In all these wells the first thick limestone reached is the Devonian, the Delaware in Ohio and the Onondaga farther east. So far as the writer is aware the nearest well to the one at Conneautville in which the Trenton limestone was reached is the Presque Isle well at Erie, Pennsylvania. The mouth of the Erie well is nearly 30 miles to the northeast of the one at Conneautville, and is some 450 feet lower, so that the Onondaga limestone was reached in it at a depth of 1,305 feet and the Trenton limestone at 4,280 feet.

A well was drilled in the western part of Spring Township in 1903 on the Powell Bros. farm, about opposite Shadeland. The mouth of the well is a few rods below the Pittsburgh and Erie Railroad track and 18 feet lower. The well was drilled by Eugene Coste, M. E., of Toronto, Canada, who furnished the following record:

Record of Shadeland (Powell Bros. Farm) Well.

Elevation above sea level 910 feet.

Formation.	Description of rock.	Thickness. Feet.	Total Depth. Feet.
	Clay soil	5	5
Ohio shales	Grayish-blue shales	1845	1850
Hamilton	Limestone	100	1950
Marcellus	Gray and black shales	135	2085
Corniferous [Onondaga]	Gray and yellow limestone	75	2160
Lower Helderberg	Hard gray and brown dolomites with flint	170	2330
	White sandstone (Sylvania ?)	20	2350
	Gray shale	6	2356

Gas was struck in 5 or 6 sandy layers in the Ohio shales from 225 to 650 feet, about enough for one boiler. At 2,335 feet a good show of light oil was struck, but immediately followed by a great deal of salt water which came up in the hole fully 2,000 feet from the bottom.

At Buffalo, New York, the average thickness of the Onondaga limestone, according to Mr. D. D. Luther is 168 feet,[1] and the formation

[1] N. Y. State Mus., Bull. 99, 1906, p. 13.

may have decreased in thickness to the 75 feet which Mr. Coste allows it in the above record. The lowest 196 feet in the well, which is referred to the Lower Helderberg, is very probably of older age; because none of the formations of the Helderbergian series of New York reaches Buffalo, and these lowest rocks in the well probably belong in the Cayugan series of New York or the Monroe of Ohio and Michigan, which is given by Luther a thickness of about 397 feet at Buffalo, New York.[1] It is only just to Mr. Coste, however, to state in this connection that until recent years the rocks of similar position have been called the Lower Helderberg in the Ohio Geological Reports.

Another well was drilled by Mr. Coste on the Frank A. Boyce farm in Beaver Township, about 1¾ miles west of the Shadeland well and about 5 miles east of the State line. The mouth of the well is 75 feet higher than that of the Shadeland according to one reading of the barometer. This, however, is not in agreement with the records furnished by Mr. Coste, which gave a difference of 135 feet. It might be stated, however, that an elevation of about 948 feet instead of 910 feet was obtained for the Shadeland well, and if 75 feet is added to this the elevation will be about 1,023 feet, or 22 feet less than that assigned by Mr. Coste. The writer is indebted to Mr. Coste for the following record of the Boyce well:

Record of Boyce Well in Beaver Township.

Formation.	Description of rock.	Thickness. Feet.	Total Depth. Feet.
	Clay soil	5	5
Ohio shales		1920	1925
Hamilton limestone and Marcellus black shale		175	2100
Corniferous [Onondaga] and Lower Helderberg limestone and flint		260	2360
Sylvania (?)	White sandstone. Some gas and large quantity of salt water	15	2375
	Hard limestone. Sulphur water in quantity at 2435 feet	335	2710
	Salt, 30 feet in thickness	30	2740
	Dark limestone and a little salt water	15	2755
	Shale	80	2835
	Dark and light colored limestone	25	2860
	Salt	10	2870
	Dark limestone	5	2875
	Salt	30	2905
	Dark limestone	4	2909

[1]Ibid., pp. 8-10.

Formation.	Description of rock.	Thickness. Feet.	Total Depth. Feet.
	Salt and limestone mixed	15	2924
	Shale	4	2928
	Salt	10	2938
	Dark and light colored limestone. Gas at 3144 feet, salt water at 3148, and a large quantity of it at 3183 feet, which is given as probably in the Clinton	245	3183

In the above record the deposits until the base of the salt is reached at a depth of 2,938 feet must belong in the Salina formation of the Cayugan series. Below that is 245 feet of dark and light colored limestone, which may perhaps belong in the Niagaran series. According to Professor Grabau the combined thickness of the Lockport limestone and Rochester shale at Buffalo in the Niagara region is from 270 to 327 feet, and, if this be true, it is possible that this well may have reached the Clinton formation.[1] This identification is corroborated by the record of the Erie, Pa., well, in which the thickness of the interval from the top of the Onondaga limestone down to the top of what was thought to be Niagaran is 745 feet, while in the above record from the top of the Onondaga limestone down to the base of the salt is 838 feet. Again in the Erie well it is only 315 feet from the top of the so-called Niagaran down to the top of the Medina sandstone. The most interesting economic fact in connection with the record of the Boyce well is the rock salt struck at a depth of 2,710 feet with a thickness of 30 feet in the first stratum and three lower ones with a thickness respectively of 10, 30 and 10 feet, making a total thickness of 80 feet of rock salt in the four strata. In addition another stratum of 15 feet thickness was reported as salt and limestone mixed. The depth at which this salt was struck, 2,710 feet, and the lowest stratum at 2,938, would be against its development; but in case it became desirable to locate salt plants in this region wells might be located in the valleys farther north, which would probably reach the salt at a more favorable depth.

Erie, Pa., Well Record.—In the above account of the Conneautville well, reference is made to the deep Presque Isle well at Erie, Pa., and since this record has never been published in a permanent way it is believed appropriate to give it in this connection. This well is located near the shore of Lake Erie, was drilled during the years of 1887 and 1888, and samples of the drillings with their depths were furnished the writer by Mr. Geo. Carroll, treasurer of the Presque Isle Natural Gas Co., and Prof. G. Guttenberg, of the Erie High School. A partial account of the upper 1,750 feet of the well was published in

[1]Bull. N. Y. State Mus., No. 45, 1901, p. 21.

the Erie Morning Dispatch of December 24, 1887, and a later one giving a similar account to a depth of 4,000 feet, both of which were written by Prof. G. Guttenberg.

Presque Isle Well at Erie.

Mouth of well about 580 feet above sea level.

No.	Depth of sample. Feet.	Description of sample.	Thickness of zone. Feet.	Total depth. Feet.
		Soil and drift	5	5
1.	60.	Bluish-olive, clay shale. A few light gray, fine-grained, micaceous sandy chips, non-calcareous	1105	1110
2.	700.	Blue, clay shale, non-calcareous		
3.	1160.	Light gray limestone, quick and strong effervescence in HCl. Top at 1110 feet, base at 1190. (G.G.)	80	1190
4.	1195.	Dark gray or bluish-gray shale, which is very calcareous, effervesces strongly at first, but effervescence does not last long. Composition largely clay, no sand. Chips rather large. Bottom at 1280 feet. (G.G.)	90	1280
5.	1300.	A very black shale, which gives a brown streak, just a trifle calcareous and almost entirely argillaceous. Bottom 1305 feet. *Marcellus shale.* (G.G.)	25	1305
6.	1311.	Dark gray limestone, which effervesces strongly in HCl. Some of the chips are rather large and contain fragments of fossils. One plicated shell which has strongly punctate structure like interior of *Orthis*. Zone from 1305 to 1325 feet, called marl by Professor Guttenberg	20	1325
7.	1330.	Rather light gray limestone (not so dark as No. 6, and chips finer), which effervesces strongly in HCl	135	1460
8.	1460.	Dark gray to blue limestone. Some of the chips are rather large. Effervescence strong in HCl. Clearly *Onondaga limestone*		
9.	1565.	Most of the chips are light gray. Can not scratch them, and they appear to be chert. A few blue ones which can be scratched, but are only slightly calcareous. Possible base of Onondaga limestone	105	1565
10.	1600.	Drab limestone, which effervesces slowly in cold HCl, but upon heating, the effervescence becomes strong. Magnesian limestone. Chips rather large.		

No.	Depth of sample. Feet.	Description of sample.	Thickness of zone. Feet.	Total depth. Feet.
		"1600 feet bottom of hard limestone." (G.G.) Perhaps base of *Bertie waterlime*	35	1600
11.	1605.	Brown magnesian limestone. It effervesces slowly in cold HCl, but much more rapidly when heated. There are some light colored, sharp grains, which effervesce very slightly in cold HCl., but disappear on heating		
12.	1640.	Chips in general like those of No. 11, but very badly iron-stained. Effervescence slight in cold HCl, but becomes very strong on heating		
13.	1650.	Very dark gray or drab in color. Effervescence slow in cold HCl, but strong when warmed. Chips finer than those of Nos. 11 and 12		
14.	1700.	Chips fine and very dark gray to blue in color. Effervescence slow in cold HCl, which is increased by heating, but does not become so strong as in Nos. 11, 12 and 13. It is apparently more shaly and argillaceous. (Marl and gypsum for 115 feet from 1700 to 1815, G.G.)		
15.	1750.	Dark gray to blue chips, which effervesce slowly in cold HCl. Chips finer than those of No. 14	450	2050
16.	1750.	Sediment from salt water, composed of $CaCO_3$ and $Ca\ SO_4+2H_2O$. (Gypsum.)		
17.	1775.	Very dark gray to blue fine chips of magnesian limestone. Effervescence slow in cold HCl, but becomes strong when heated		
18.	1780.	Very dark drab to brown fine chips, which effervesce slowly in cold HCl, but strongly when heated		
19.	1790.	Very dark gray, fine chips, which effervesce slowly in cold HCl, and strongly when heated		
20.	1805.	Gray or drab magnesian limestone, with very fine chips, which effervesce slowly in cold HCl and strongly when heated.		
21.		Ditto		
22.	1820.	Light gray to drab limestone, chips rather coarser than in preceding sample, which effervesce rather readily in cold HCl. (There is no sand in Nos. 20 and 22 as reported by G.G.)		
23.	1840.	Very dark gray, really blue, limestone, some of the chips rather large, which effervesces moderately in cold HCl and more strongly on heating		

No.	Depth of sample. Feet.	Description of sample.	Thickness of zone. Feet.	Total depth. Feet.
24.	1860.	Mainly drab chips, some of them blue, in part of fairly good size. Rather strong effervescence in cold HCl, which increases after being in the acid a short time and becomes strong		
25.	2020.	A blue marl or shale, which effervesces slowly in cold HCl and apparently contains a considerable percentage of argillaceous material		
26.	2050.	Very dark gray to blue limestone, which effervesces slowly in cold HCl and much more strongly when heated. It contains a good many impurities. In some characters resembles the Lockport limestone		
27.	2100.	Dark gray, bluish-gray and blue chips of rather impure limestone. Effervesces slowly in cold HCl. The sample is about the same as No. 26, only chips slightly larger		
28.	2150.	Dark gray and blue limestone; most of the chips are fine; effervesces slowly in cold HCl, more strongly after a short time	250	2300
29.	2175.	Dark blue, very compact limestone, which effervesces very slowly at first in cold HCl, but increases after a short time. Part of chips large and with sharp edges. Typical *Lockport limestone*		
30.	2200.	Brownish, very fine grains, which when examined singly, appear to be almost white. Effervesces very slowly in cold HCl, but upon heating it becomes strong and very little residue is left		
31.	2230.	Almost precisely the same as No. 30		
32.	2300.	Similar to Nos. 30 and 31. Effervesces slowly in cold HCl, but after heating there is very little residue. A magnesian limestone. (Below is fossiliferous shale. No sample from between 2330 and 2365. G.G.)	65	2365
33.	2365.	Nearly all very coarse, dark red to chocolate colored chips, which are mainly finely arenaceous, but a few are apparently argillaceous. Also a few arenaceous, greenish chips. There is a slow effervescence in cold HCl, which is increased considerably for some time by heating, but a large residue is left. (Bottom of this zone at 2455, making 90 feet. G.G.) *Upper Medina*	90	2455
34.	2460.	Very fine grains of quartz sand, color of		

No.	Depth of sample. Feet.	Description of sample.	Thickness of zone. Feet.	Total depth. Feet.
		whole brownish-red (probably due to iron rust) but separate grains appear to be white. (Was white at first, G.G.) No effervescence when heated in HCl. (Slight showing of gas. Bottom of zone at 2530, giving a thickness of 75 feet for it. G.G.) *Gray Medina*	75	2530
35.	2540.	Mainly blue, argillaceous shale, with an occasional chip of very fine-grained, light gray to greenish-gray sandstone. (Bottom at 2600 feet, making zone 70 feet thick. Shale with some sand. G.G.)	70	2600
36.	2800.	Very dark red to reddish-brown, argillaceous shale. There is a little fine sand, but it is not gritty to any extent. Non-calcareous. Contains a few chips of greenish-gray sandstone. (This zone commences at 2600 and continues to 3384 feet, giving a thickness of 784 feet. G.G.)		
37.	2960.	Color same as No. 36. Part of the chips are clearly argillaceous shale, but a portion are arenaceous, the grains very fine and compact. More of the greenish-gray sandstone than in No. 36	784	3384
38.	3340.	Color about the same as Nos. 36 and 37. Part argillaceous shale and part arenaceous, with very fine grains of sand which are closely cemented. Slightly calcareous		
39.	3385.	Two-thirds of sample red, arenaceous and argillaceous shale like Nos. 36–38; one-third greenish, somewhat arenaceous shale. The grit is very fine and part of the shale is very argillaceous. Change in this sample from the Medina to the Lorraine (?) and the bottom of the Medina is reached at about 3384 feet		
40.	3395.	Greenish-gray shale, most of which is somewhat arenaceous; but some of the chips are pure clay shale. Slightly calcareous. Some red chips. *Lorraine*		
41.	3780.	Blue, argillaceous shale, which is not sandy and is calcareous, so that it effervesces freely in cold HCl. (Gray shale from 3385 to 3900 feet, making its thickness 515 feet. G.G.)	896	4280
42.	3930.	Dark blue shale which is argillaceous, with an occasional arenaceous chip, and also some that are mainly limestone.		

No.	Depth of sample. Feet.	Description of sample.	Thickness of zone. Feet.	Total depth. Feet.
		Fragments of plicated fossils. (Dark gray shale from 3900 feet to at least 4020 feet, making its thickness at least 120 feet. G.G.)		
	4080.	From 4080 feet for an additional depth of 200 feet a dark shale was reported by Professor Guttenberg		
	4280.	Dark, hard rock was reported, the chips of which indicate an impure, fossiliferous limestone. The writer's samples from below 3930 feet have been mislaid; but at the time of examination in November, 1888, it was recorded that the top of the Trenton limestone was reached at 4280 feet, which is believed to be correct	170	4450
	4350.	Rock was reported as drab colored, hard, fossiliferous limestone, which contained 86 per cent $CaCO_3$		
	4450.	Bottom of well, which was reported as still in the Trenton limestone		

The depth of the Erie well makes its record an important one for geologists, and it is to be regretted that the writer was unable to obtain a more complete set of samples of some parts of the well for examination. However, in spite of the uncertainty about the line of division between certain formations it is believed that this record is a most valuable one for those interested in the geology of northwestern Pennsylvania and northeastern Ohio.

The upper rocks of this well are in the Portage flags, according to Dr. White's report and geological map of Erie County.[1] In this report the Portage flags are described as overlain by the Girard shale of Dr. White, which in turn is succeeded by the Chemung formation. Later investigations conducted by Dr. John M. Clarke in southwestern New York and Erie County, Pa., led him to state that "the Portage, it has now been made evident, does not there [Erie County, Pa.] exist, and the faunistic value of the Girard shales is a matter for further study."[2] The distribution of the Portage division in western New York is shown on the accompanying "Stratigraphic map"[3] by Dr. Clarke and Mr. Luther, where its top is represented as extending along the shore of Lake Erie to only a short distance to the west of Westfield. This was also essentially the limit of the Portage formation as represented on the "Geological Map of New York" of 1901, where the top of this formation passed beneath the lake level in the northeastern part of

[1]Second Geol. Surv. Pa., Q^4, p. 119 and sheet 1, Geological Map of Crawford and Erie Counties.

[2]N. Y. State Mus., Bull. 69, 1903, p. 853.

[3]This map also appears in ibid., Mem. 6, pt. 2, 1904, op. p. 199.

Ripley Township (the last one in New York) about half way between the villages of Ripley and Westfield. And again Dr Clarke stated that "the 'Portage' and 'Girard shales' of Erie County, Pennsylvania, are later than Portage time."[1] Finally, Mr. Luther told the writer in March, 1907, that he had collected Chemung fossils in Ripley, which is on the New York-Pennsylvania line, down to the level of Lake Erie. He had also collected Chemung Brachiopods in the glen near the lake at Northeast, which is in the northeastern part of Erie County, Pennsylvania, as he had published in 1903.[2]

At a depth of 1,110 feet a light gray limestone was reached which is thought to be in the Hamilton formation. The 25 feet of very black shale, the base of which was reached at a depth of 1,305 feet, appears to be undoubtedly the Marcellus shale. There may be a question whether the 20 feet of dark-gray limestone from 1,305 to 1,325 feet, which Professor Guttenberg called marl, is in the Onondaga limestone. It may perhaps represent the eastern continuation of a more impure superjacent limestone, the surface exposures of which in Ohio are known as the Delaware limestone. It appears certain, however, that the light gray limestone of the sample from a depth of 1,330 feet is in the Onondaga. This zone is reported to have been reached at 1,325 feet, and the sample from 1,460 feet is also that from a limestone composed largely of $CaCO_3$. The average thickness of the Onondaga limestone in the wells in the vicinity of Buffalo is given as 168 feet by Mr. Luther,[3] and if the 20 feet of dark limestone be added to the subjacent 135 feet it will give at least 155 feet of the Onondaga limestone in this well. H. P. H. Brumell of the Geological Survey of Canada gave the thickness of the Corniferous (Onondaga) limestone in southern Ontario as varying from 160 to 300 feet.[4] It is not improbable, however, that the sample from 1,565 feet, which is apparently composed mainly of chert, is also still in the Onondaga, since chert in large quantity is of rather infrequent occurrence in the lower magnesian limestones. If this chert zone belongs in the Onondaga limestone, then the thickness of the formation in this well ranges from 240 to 260 feet. The sample of drab magnesian limestone from a depth of 1,600 feet is reported to be the base of hard limestone, and that horizon may represent the base of the Bertie waterlime of the upper Salina, which Mr. Luther gives as 53 feet thick at North Buffalo.[5] There is some evidence tending to show the presence of the Cobleskill limestone on Kelleys Island, which directly overlies the Bertie limestone at Buffalo with a thickness of from 7 to 9 feet, and consequently it may be represented in the Erie well. The

[1]Bull. Geol. Soc. America, Vol. XIV, 1904, p. 536.
[2]N. Y. State Mus., Bull. 69, p. 1028.
[3]N. Y. State Mus., Bull. 99, 1906, p. 13.
[4]Bull. Geol. Soc. America, Vol. IV, 1893, p. 227; and Ann. Rept. Geol. Survey Canada (N. S.), Vol. V, pt. 2, 1893, Rept. Q, p. 5.
[5]N. Y. State Mus., Bull. 99, p. 9.

sample of blue marl or shale from a depth of 2,020 feet appears to belong in the Salina formation, which probably extends to a depth of 2,050 feet. This gives a thickness of from 470 to 585 feet for the Cobleskill and Salina formations. In the Buffalo region the thickness for these same formations amounts to 398 feet, and from the top of the Onondaga limestone down to the base of the Salina is 566 feet, while in the Erie well it is apparently 745 feet. The Lower Helderberg limestones which appear in the older records of wells in Ontario and Ohio are not listed in the Erie well, because it has been shown in recent years that the formations of this series, which are typically developed in the Helderberg Mountains of eastern New York, do not extend as far west as Buffalo. It is a question whether the Guelph limestone which overlies the Lockport limestone in Ontario with a thickness of from 140 to 160 feet[1] occurs in the Erie well but its stratigraphic position is indicated in the following diagrammatic section of this well. Apparently the Guelph and Lockport limestones extend from 2,050 feet to 2,300 feet, with a thickness of 250 feet. In Ontario these two limestones are reported by Mr. Brumell to have a thickness of 240 feet in a well in Bertie Township,[2] which is the one bordering Lake Erie just west of the Niagara River and Buffalo; while in the one at Port Colborne, which is farther west at the Lake Erie end of the Welland Canal and about north of Fredonia, New York, they are listed as 218 feet thick,[3] but apparently at least some of the Rochester shale is also included in this interval. Below this limestone in the Erie well Professor Guttenberg reported fossiliferous shale, while the red rocks of the Medina formation were reached at a depth of 2,365 feet. Apparently in that interval of 65 feet is the Rochester shale and Clinton formation, samples of which were not seen by the writer. In the Bertie well, cited above, the Niagara (Rochester) shale and Clinton formation are 80 feet in thickness. From the top of the red rocks at a depth of 2,365 to their bottom at 3,384 feet is 1,019 feet, all of which apparently belongs in the Medina formation. In this connection Medina is used in the old sense and not with the restricted limit proposed by Professors Grabau[4] and Chadwick.[5] For the lower red Medina shales Professor Grabau proposed the name of Queenstown beds,[6] and Professor Chadwick revived the early name of Lewiston shale.[7] The Medina formation on the Niagara River is given a thickness of 1,266 ± feet by Grabau,[8] and in the Port Colborne well Brumell refers 770 feet to this formation. In

[1]Ann. Rept. Geol. Survey Canada (N. S.), Vol. V, pt. 2, Rept. Q, p. 5.
[2]Ibid., p. 37.
[3]Ibid., p. 34.
[4]Science, N. S., Vol. XXXVII, April 17, 1908, p. 623 and ibid., Vol. XXIX, February 26, 1909, p. 356.
[5]Ibid., Vol. XXVIII, September 11, 1908, p. 347.
[6]Ibid., Vol. XXVII, p. 622.
[7]Ibid., Vol. XXVIII, p. 347.
[8]Bull. N. Y. State Mus., No. 45, 1901, p. 21.

the samples of a Port Colborne well which the writer studied over twenty years ago, the red sandstone of the Medina was struck at a depth of 711 feet which the drill penetrated to a depth of 1,500 feet without reaching its bottom, giving a thickness of at least 789 feet for the Medina formation. The top of the Lorraine was reached at a depth of about 3,384 feet and the top of the Trenton limestone at 4,280 feet, which gives a thickness of 896 feet for the Lorraine formation and Utica shale in the Erie well. The lower 200 feet of this interval was reported by Professor Guttenberg as a dark shale which probably belongs in the Utica. Grabau reported these two formations as 630 feet thick in the Niagara River region,[1] and in the township of the Brantford well, Ontario, which is about north of Erie, Brumell reported the Hudson River (Lorraine) and Utica as 980 feet thick.[2] The Erie well according to the reports of Professor Guttenberg entered the Trenton limestone to a depth of 170 feet, which including the Black River limestone is given a thickness of from 680 to 720 feet in the Niagara River region by Grabau,[3] and in the St. Catharines well, Ontario, which is about north of Port Colborne, Brumell reported 667 feet when a white quartzose sandstone was struck.[4]

The well was a failure so far as commercial results were concerned. At 2,455 feet in the gray Medina sandstone a slight flow of gas was obtained which lasted for a few days. Salt water was struck at 1,620 feet and again at 2,200 feet, where there was a strong flow and also H_2S.

A condensed diagrammatic record of the Erie well is given in the following section:

[1]Ibid., p. 21.
[2]Loc. cit., p. 44.
[3]Loc. cit., p. 21.
[4]Loc. cit., p. 32.

Condensed Record of Erie Well.

Altitude about 580 feet above sea level.

Depth.			
0'			
	5'	Soil and drift	
5'			
	1105'	Chemung (?) Portage Genesee	
1110'			
	170'	Hamilton	
1280'			
	25'	Marcellus	
1305'			
	20'	Onondaga limestone (?)	
1325'			
	135'	Onondaga limestone	
1460'			
	105'	Perhaps Onondaga	
1565'			
	35'		Cobleskill limestone (?) and Salina formation 485' to 590'
1600'		Base of Bertie waterlime (?)	
	450'		
2050'		Base of Salina (?)	
	250'	Guelph (?) and Lockport	
2300'			
	65'	Rochester shale and Clinton	
2365'			
	90'	Red Medina	Medina formation 1019'
2455'			
	145'	Gray Medina	
2600'			
	784'	Lewiston	
3384'			
	896'	Lorraine and Utica	
4280'			
	170'	Trenton limestone	
4450'		Bottom of well	

In the above section the line between the Onondaga and Cobleskill limestones (or if the latter is absent then between the Onondaga limestone and Bertie waterlime) is one of the most difficult to determine. It is not at all improbable that part or all of the 105-foot interval between 1,460 and 1,565 feet belongs in the Cobleskill-Salina division; but on account of the chert at its base it was not included in this latter division.

A generalized section giving the thickness of the rocks along the Ohio-Pennsylvania State line from the base of the Sharon conglomerate down to the top of the Trenton limestone has been prepared. This generalized section is based upon the sections near Orangeville and on Mill Creek, in the southern part of Kinsman Township, for the interval from the Sharon conglomerate to the Berea sandstone, and upon the Orangeville well and the section one-half mile north of Williamsfield P. O. for the thickness of the Berea formation. For the interval from the Berea formation to the Onondaga limestone the well records at Andover and Conneautville were used. The Andover well began in the Berea and reached the Onondaga at 2,500 feet, and in the Conneautville well the Onondaga was reached at 2,352, while the interval from the mouth of the well to the base of the Cussewago sandstone was estimated from barometric readings as 110 feet, which would then make the entire interval from the Berea to the Onondaga 2,462 feet; 2,460 feet was used in the section. Finally, the interval from the top of the Onondaga limestone to that of the Trenton limestone was taken from the record of the Erie well.

A Generalized Section from the Sharon Conglomerate to the Trenton Limestone along the Ohio-Pennsylvania State Line.

Thickness			
0′		Base of Sharon conglomerate	
	300′±	Cuyahoga 275′-300′	Shenango, Meadville, Sharpsville, Orangeville
300′			
	105′	Berea 105′-122′	Corry, Cussewago
405′			
	2460′	Bedford and Ohio shale	Riceville, Venango, Chemung, Girard, Portage, Genesee, Hamilton, Marcellus
2865′			
	260′—	Onondaga 155′-260′	
3125′			
	485′+	Cobleskill and Salina	
3610′			
	250′	Guelph and Lockport	
3860′			
	65′	Rochester and Clinton	
3925′			
	1020′	Medina	
4945′			
	895′	Lorraine and Utica	
5840′		Top of Trenton limestone	

Cherry Valley and Wayne Townships.—In Ashtabula County, Ohio, to the west of Andover and Williamsfield townships respectively, are those of Cherry Valley and Wayne. Pymatuning Creek flows in a southerly direction across the eastern portion of both townships; but the higher ground to the west of the creek does not afford so many

sections of the underlying formations as are to be found along the streams on the eastern side of the Pymatuning.

A stream flows part way across the southern portion of Cherry Valley Township and in the northeastern part of Wayne Township enters Pymatuning Creek. Outcrops of rocks occur on this stream just above and west of the highway bridge on the first north and south road to the west of the Lake Shore and Michigan Southern Railroad (Low Grade Cutoff) and Pymatuning Creek and on the Horace Mann farm. In the summer of 1910 rocks were also lying beside the road which came from excavations for the abutments of the new bridge. Some of these rocks are fine-grained sandstones and others are soft argillaceous shales, part of which weather to a slightly reddish color. In the sandstones or arenaceous shales from this excavation specimens of *Spirifer disjunctus* Sowb., *Reticularia præmatura* (Hall) Schuchert and other Chemung fossils were collected.

On the southern bank of the stream a short distance above the bridge is a ledge, about 4 feet of which is fairly well shown, composed of bluish-gray sandstone, which in general is rather thin-bedded although some of the layers are a little thicker, alternating with bluish shales. Some of the sandstone layers are somewhat calcareous and rather fossiliferous. The most abundant species is *Spirifer disjunctus* Sowb., but *Productella* is common and several other species occur. This is a Chemung fauna and it occurs at this locality well toward the top of the Chagrin formation. The complete list of species is as follows:

1. Spirifer disjunctus Sowb.------------------------------------ (a)
   Specimens from this locality were compared with authentic ones of this species at Cornell, and with types in the New York State Museum, and there is no question as to their identity.
2. Camarotœchia orbicularis Hall -------------------------------- (r)
   Compared with types of this species in the New York State Museum.
3. Camarotœchia stephani Hall --------------------------------- (r)
   The plications are rather coarser than on specimens of corresponding size of *C. eximia* Hall from the Ithaca formation at Ithaca, N. Y., in the Cornell Museum, and although the Ohio specimens are not so elongated, as is generally the case with Ithaca ones of *C. stephani*, still it is probably better to refer them to this species.

   A specimen was compared in the American Museum with the original of fig. 10, pl. 55, Vol. IV, Pal. N. Y., of *C. stephani*, from Cortland County, N. Y. The Ohio specimen is smaller; but it is very similar in outline. The plications are a little smaller than on the type, as might be expected since the specimen is smaller. The Ohio form has 4 strong plications in the sinus and a less conspicuous one on each side,making 6 in all in the sinus, and 7 on each side, which makes 20 plications altogether.

The length and width of these two specimens are as follows:

	Ohio specimen.	Cortland, N. Y., specimen.
Length ----	13.6+ mm.	16.4 mm.
Width------	14.7 "	13 "

This shows that the width of the Ohio specimen is somewhat greater in proportion to the length than that of the New York type.

There are other specimens which were compared with authentic ones of *C. eximia* from the Ithaca formation at Cornell, and it was found that the plications on the Ohio specimens are rather coarser than on those of *C. eximia* of corresponding size. Although these specimens are not so elongated as *C. stephani* generally is, perhaps it is better to refer them to this species. In the American Museum it was noted that their outline is not far from that of the type specimen of *C. eximia* shown by fig. 1 of pl. 55, which is a small dorsal valve from the "Inclined Plane" at Ithaca, N. Y., without any distinct fold, and with 28 somewhat angular plications. It was decided, however, that it is perhaps as well to list these specimens as *C. stephani* Hall (?). Professor Hall gave the occurrence of this species as in the Chemung near Ithaca [Ithaca formation for that locality], at Phillipsburg, Allegany County, and Cortland County, N. Y., and near Bedford, Pa., which is not changed in Professor Schuchert's Synopsis of fossil Brachiopoda.

4. Athyris polita Hall -- (r)

A small specimen with conspicuous lines of growth, and other larger ones, some of which are considerably distorted.

5. Chonetes setiger Hall -- (rr)

This specimen agrees fairly well with some at Cornell from the Chemung of Ellicottville, N. Y., labeled *C. setiger*, and with others from the Ithaca formation, near Ithaca, N. Y. It also agrees closely with fig. 3, pl. 22, Vol. IV, Pal. N. Y., from Penfield, Ohio, concerning which Hall wrote that "there may be some question as to absolute identity." The range of this species is given by Professor Schuchert as from the Marcellus to the Waverly.

6. Productella hirsuta Hall-- (rr)

The spines are smaller than those of *P. lachrymosa* (Con.) Hall. It was compared with a type specimen of this species in the American Museum, and the identification is believed to be correct. Professsor Hall gave this species as from the Chemung of Phillipsburg and Rockville, Allegany County, N. Y., and Covington, Pa., which remains the same in Professor Schuchert's Synopsis of fossil Brachiopoda.

7. Productella lachrymosa (Con.) Hall ---------------------------- (r)

The specimens from this locality were compared with authentic ones of this species, and also of its variety *lima* Con., at Cornell University, and with type specimens of both the species and variety at the New York State

Museum. Conrad stated in the original description that the variety differs from the species "in the depressed middle [of the ventral valve], much more numerous shorter tubercles." The original of figs. 29, 30, pl. 25, Vol. IV, Pal. N. Y., of *P. lachrymosa* var. *lima* from the Chemung of Ellington, Chautauqua County, N. Y., is a very gibbous ventral valve without any indication of a mesial sinus. The pustules from which the spines arise are perhaps a little smaller than those on the specimen shown in fig. 26, pl. 25, of *P. lachrymosa*, which also shows those along the hinge margin as stated in the specific description. The original of fig. 31, pl. 25, of the variety *lima*, has a decided mesial sinus; but the pustules are as large as those on any specimen of *P. lachrymosa* and no more abundant. A row of 4 spines is well developed on the hinge margin. The original of fig. 27, pl. 25, of *P. lachrymosa*, when contrasted with the original of fig. 31 of the variety *lima*, shows a broad, but not nearly so deep and clearly defined ventral sinus, while the pustules from which the spines arise are shorter and more numerous on the latter (the variety) than on the former specimen, which belongs to the species. The examination of these types shows that not all of those which were called variety *lima* have a prominent median sinus on the ventral valve; but in general, the pustules of the variety are not so elongated, and are more numerous than on the species. *P. lachrymosa* var. *stigmata* Hall is shown on examination of the type specimens of the ventral valve, to be more gibbous and narrower in proportion to the length than the specimens of either *P. lachrymosa* or its variety *lima*, while the fossets (pits) or pustules, which indicate the bases of the spines, are much more remote than on either *P. lachrymosa* or variety *lima*. After this examination of the types, it appears better to refer most of the specimens from this locality simply to the species *P. lachrymosa* (Con.) Hall. The occurrence of this species was given by Hall as the Chemung of southern and southwestern New York, which was not changed by Professor Schuchert in the Synopsis of fossil Brachiopoda.

8. Productella lachrymosa (Con.) Hall var. lima Con. (?)---------- (rr)

One specimen from this locality is a ventral valve which resembles considerably fig. 27, pl. 25, of *P. lachrymosa*, and also fig. 31 of the variety *lima*. The sinus has about the strength of that on *P. lachrymosa*; but the pustules are smaller and more like those of the var. *lima*. Another specimen is a considerably larger ventral valve (internal impression), with a rather deep, but not very broad sinus. It is stronger, however, than that on type specimens of *P. bialveata* Hall. The five type specimens of *P. bialveata*, figs. 24–28, pl. 26, are all on one block of sandstone from Meadville, Pa., associated with *Spirifer disjunctus* Sowb. The pustules, as shown on fig. 28, are fairly large and rather distant. The median sinus does not begin to be conspicuous until about one-third the

distance from the umbo to the front of the valve. It increases in strength toward the front of the valve; but is never broad like the sinus on some valves of *P. lachrymosa* var. *lima*. This species, however, is likely to be found in the upper Chagrin of Ohio. It appears fairly certain that the two specimens described above, from Cherry Valley Township, Ohio, may be identified as *P. lachrymosa* (Con.) Hall var. *lima* Con. The occurrence of this variety was given by Hall as in the Chemung of southwestern New York, to which distribution Professor Schuchert has added the Eureka district, Nevada, and Mackenzie River, Canada, all of which he gives as Chemung.

9. Ambocœlia umbonata (Con.) Hall var. gregaria Hall----------- (rr)

The specimen was compared with a type in the New York State Museum, and it has the rather narrow and fairly deep sinus of this variety.

10. Schuchertella chemungensis (Con.) Girty---------------------- (r)

An Ohio specimen agrees closely with others at Cornell from South Cuba, N. Y., which were identified by Professor Williams as this species, and with still others from Meadville, Pa., so identified by Dr. Kindle. It was also compared with the original of fig. 10, pl. 10, Vol. IV, Pal. N. Y., in the New York State Museum, from Randolph, N. Y. The Ohio form is wider in proportion to its length than this hypotype in the State Museum; but the lines (striæ) are subequal and bifucate in the same way, two or three times on both specimens. The identification is apparently correct. Hall gave the occurrence of this species as in the Chemung of southern New York, to which Professor Schuchert has added the Chemung of Pennsylvania; Eureka district, Nevada; Lake Winnipegosis, Canada, and Waverly group of Ohio; while Professors Graubau and Shimer give it as in the Chemung of New York, Pennsylvania, Ohio, Nevada, and Manitoba.[1]

11. Pararca sao Hall --- (rr)

This specimen agrees closely with one so labeled in the U. S. Devonian collection at Cornell, from Meadville, Pa., except that the specimen is only about two-thirds the size of the Ohio one, and the radiating plications are correspondingly smaller. This specimen has about the same proportions, length 45 mm. and height 33mm., as the smaller one described by Hall, which is given as 45 mm. in length and 32 mm. in height. Hall gave the occurrence of this species as in the Chemung group at Meadville, Pa., associated with *Spirifera verneuili* Murch. =*Spirifer disjunctus* Sowb., and also near Uniontown, Pa.

12 Pararca cf. venusta Hall ------------------------------------ (rr)

A specimen which is 34 mm. long and 28 mm. high, agreeing fairly well with the description of this species, except that the umbonal slope is stronger. The outline of the figure (Pal. N. Y., Vol. V, pt. I, Lamellibranchiata

[1]North Am. Index Fossils, Vol. I, 1907, p. 230.

II, pl. 94, fig. 22), however, does not agree well, and in this respect it is more like *P. erecta* Hall, only it is longer in proportion, from the Waverly of Warren, Pa. *P. venusta* was given by Professor Hall as from the upper part of the Chemung at Warren, Pa., and above the conglomerate at Panama, N. Y.

13. Spathella cf. typica Hall -- (rr)

The specimen resembles considerably certain ones of this species from Chemung County, N. Y., the originals of figs. 37, 39 and 40, pl. 66, Lamellibranchiata II, pt. I, Vol. V, Pal. N. Y., and also somewhat the one represented by fig. 40. The occurrence of this species was given by Professsor Hall as the Chemung of Ithaca [for this locality it is Ithaca formation], near Elmira and Lindley Township, Steuben County, N. Y., and in Sullivan, Tioga and Bradford counties, Pa.

This fauna is an interesting one since it occurs only 50 feet below a sandstone which is referred to the lower part of the Berea formation, and consequently its horizon is well toward the top of the Chagrin formation. Of the 13 species in the list 11 are identified specifically with a reasonable degree of certainty. Of these 11 species *Spirifer disjunctus* occurs in the Chemung and Mississippian, *Camarotœchia stephani* in the Portage and Chemung and *Chonetes setiger* from the Marcellus to the Waverly. The other 8 species, viz., *Camarotœchia orbicularis, Athyris polita, Productella hirsuta, P. lachrymosa, P. lachrymosa* var. *lima, Ambocœlia umbonata* var. *gregaria, Schuchertella chemungensis,* and *Pararca sao* are confined to the Chemung. Again 4 of these 11 species, *Spirifer disjunctus, Productella lachrymosa, Ambocœlia umbonata* var. *gregaria* and *Schuchertella chemungensis,* occur in the list of 12 dominant species of the *Spirifer disjunctus* fauna of Chautauqua County, N. Y., compiled by Professor Williams, while *Chonetes setiger* is related to *C. scitulus* of the dominant list.[1] Also 3 of the 11 species, viz., *Spirifer disjunctus, Productella hirsuta* and *Schuchertella chemungensis* occur in the *Spirifer disjunctus* fauna and its dominant associates of the Genesee section as compiled by Professor Williams, while *Chonetes setiger* and *Ambocœlia umbonata* var. *gregaria* are related to *C. scitulus* and *A. umbonata* of that list.[2]

The above statistics show that this Cherry Valley fauna in eastern Ohio, 9 miles west of the Ohio-Pennsylvania State line, and near the top of the Chagrin formation, is a Chemung fauna, since all of the 11 species occur in that formation and 8 are confined to it. Again part of these species are recognized as diagnostic or dominant species of the Chemung of southwestern New York and nearly, if not all, occur more abundantly in the Chemung than in any other formation. It, therefore, ap-

[1]Bull. U. S. Geol. Survey, No. 210, 1903, p. 86.
[2]Ibid., p. 87.

pears that the rocks containing this fauna are of the age of the Chemung of southwestern New York, unless this Chemung fauna continued to live in rocks of later age in Ohio than in New York. From the evidence of the fauna, unless proof is found that it lived to a later age in Ohio than in New York, it would appear that these rocks should be correlated with the Chemung formation of New York. On the other hand, if this Chemung fauna survived later as it is followed westward, then it is possible that this upper part of the Chagrin may represent some portion of the Conewango formation of northwestern Pennsylvania, or of the Cattaraugus and Oswayo formations of southwestern New York, or even the Bedford, which is the lowest formation of the Ohio Waverly.

The stream was followed up from the bridge, and Chagrin fossils with *Spirifer disjunctus* Sowb. were found in both blue shale and thin-bedded bluish-gray sandstone 16 feet higher than the top of the ledge just above the bridge, while the thin-bedded bluish-gray sandstone ripple-marked, was seen in the bed of the run still 5 feet higher. The stream above this point is bordered by dirt beds and farther up it flows through a somewhat marshy tract.

On the next north and south road, one mile to the west of the one on which the bridge mentioned above occurs, in the highway gutters just north of this run, and a short distance below the house of Mr. Hiram Crosby, in 1910 were outcrops of a very soft and friable sandstone of light brown color. This sandstone is composed of grains of fairly coarse quartz sand which is cemented so loosely that it crumbles to sand when struck, and might readily be taken for a bed of rather compact and massive sand. In the gutter on the western side of the road about 2½ feet was shown, and it also occurred in the gutter on the eastern side of the road at a little lower horizon, making altogether some 5 or 6 feet of massive, very friable sandstone with no bedding planes, which is more or less perfectly exposed. This sandstone has the lithologic characters and stratigraphic position of the Cussewago sandstone of Pennsylvania, which is considered as the equivalent of the lower portion of the Berea of Ohio. The run below is in somewhat marshy land apparently fed by springs from the low hills bordering it, this very porous sandstone serving as a reservoir for the water.

On the opposite side of the run from the outcrop of sandstone just described, a well was drilled to the depth of 168 feet some 25 years ago on the farm of Mr. E. F. Williams, which lies to the west of the highway. According to Mr. Williams, who lived on the farm when the well was drilled, its record is as follows:

Record of Well on Williams's Farm.

Depth		
0′	4′	Soil
4′	12′	Sand rock
16′	152′	All slate rock, in which some gas was obtained
168′		Bottom of well

The mouth of this well is about 15 feet lower, barometrically, than the top of the sandstone as exposed in the gutter on the northern side of the run.

The following section is compiled from data secured at this locality and the outcrops down the run to the bridge on the next north and south road to the east:

No.		Thickness. Feet.	Total thickness. Feet.
5.	*Berea sandstone* (*Cussewago*). Very friable sandstone of light brown color, composed of grains of fairly coarse quartz sand	5+	80
4.	Covered interval	10	75
3.	Sand rock in well on the farm of Mr. E. F. Williams	12	65
2.	Covered interval	28	53
1.	*Chagrin formation.* Thin-bedded, bluish-gray sandstones, alternating with bluish shales, in which *Spirifer disjunctus* Sowb. is found, associated with other Chemung fossils, to within 5 feet of the top of the outcrops	25	25

A well was drilled in 1897 by the Western Reserve Oil Company, on the Titus A. Hayes farm, which is located nearly a mile north of Wick. From woodchuck holes in the vicinity of the mouth of the well are rocks resembling lithologically those of the Chagrin formation, although possibly they may be Bedford. At a depth of 2,460 feet the top of the Devonian limestone was reached. Four samples from this well were examined which gave the following section:

The Hayes Well North of Wick.

Depth of sample. Feet.	Description of sample.
2460.	*Devonian* (probably *Onondaga*) *limestone.* Light gray limestone, which effervesces strongly in cold dilute HCl.
2640.	Sample supposed to be from this well composed of fine grains of quartz sand. *Sylvania sandstone* (?).

Depth of sample. Feet.	Description of sample.
2656.	Similar fine grains of quartz sand, which are slightly discolored by rust. Also with a slightly saltish taste.
2662.	Fine white grains, mainly of quartz sand; but there are a few calcareous ones.

Gas was obtained from this well at a depth of about 600 feet, which they had used for about 6 years (in August, 1904) for lighting and heating the house. The pressure at that time was stated to be just about the same as at the beginning and had remained steady. This well is about opposite the section located above the village of Williamsfield P. O., which has already been described.

Mr. L. J. Hayes, who drilled this well on his brother's farm, has furnished the following record:

Record of Hayes Well North of Wick.

Description.	Thickness. Feet.	Depth. Feet.
About 50 feet of sandstone, running from that into shale. [Perhaps this is Berea sandstone; but the rocks seen in woodchuck holes near the mouth of the well resembled the Bedford or Chagrin formations]	50	50
Shale	1190	1240
Mixed sand, very dark in color, resembling the Bradford oil sand, from 8 to 12 feet thick. A slight show of oil in this sand	10±	1250
Shale	600	1850
Red rock, about 40 feet thick	40±	1890
Shale	510	2400
Hard rock, which for the first 50 feet resembled very closely the Trenton limestone. [Top of Devonian limestone.]	50	2450
Very hard for a few feet; sand of light gray color. [Possible a chert zone.] Then limestone for about 200 feet, without any material change except from hard to softer rock	200±	2650
After going through the limestone about the same kind of rock as that above the limestone, with very little change except from fine to a shade coarser. This continued to the bottom of the well at 2840 feet	190	2840

Mr. Hayes states that this well was the driest he ever drilled, not the slightest show of water after the casing was put in. After it was finished and had stood four months the bailer was run to the bottom of the well and there was not enough water to wet it.

On the Wick-Williamsfield P. O. road, in the ridge just to the east of Pymatuning Creek, are big beds of sand which are shown in the highway cut.

The present Wick is the same as the old village of Lindenville,

which on Read's geological map is represented as located on the outcrop of the Berea grit. The present Lindenville is located at the first four corners to the west of Wick, a distance of one mile.

In bed of stream to the west of the north and south road, about one-half mile south of Wick, is an outcrop of greenish (when wet) coarse-grained, soft sandstone. This is about as soft as the Cussewago sandstone of northwestern Pennsylvania, which it apparently represents, and occurs on the line of outcrop of the Berea grit as represented by Read on his geological map.

This stream continues south of the Wick-Lindenville highway until about one-half mile west of the latter hamlet, where it forks. The rise of this stream is not rapid, along which rocks, with some covered intervals, are shown for a distance of $1\frac{1}{4}$ miles to the west of the outcrop just described on the highway south of Wick. This carries the top of the section above Lindenville, the detailed account of which is given below:

Section along Stream South of the Lindenville-Wick Road.

No.		Thickness. Feet.	Total thickness. Feet.
9.	*Orangeville shale.* Two feet of soft, argillaceous shale is shown on the creek bank above Lindenville, which has the lithologic character of the Orangeville. Bluish, argillaceous shale is shown in the stream bed 5 feet below the shale already noted, on the stream bank	7	125
8.	Covered interval	15	118
7.	*Berea formation.* Layers of fine-grained sandstone, 2 inches or more in thickness, in bed of stream. The top of rather thin-bedded and rather fine-grained, micaceous sandstone is shown in the field, at about the same level as the sandstone in the stream, below the east and west road leading into Lindenville, and a short distance south of that hamlet	6±	103
6.	Massive, coarse-grained sandstone, some of which contains abundant nodules of clay ironstone. The upper layer on the cliff varies in thickness from 2 feet 8 inches to 2 feet 10 inches, and in the bed of the stream is about 4 feet. The lower part of this zone is a massive, rather coarse-grained sandstone of rusty or brownish color, as shown on the bank of the stream, and it breaks off in big blocks	9±	97
5.	Bluish, generally arenaceous shales, alternating with layers of flaggy sandstone, but the shales predominate. Some of the blue shale is argillaceous rather than arenaceous. The upper 8 to 10 feet of this zone is very blue, rusty as weathered, and lithologically does not differ from shale which may be found in the upper Cuyahoga. Some of the thicker and sandy layers are, however, conspicuously ripple-marked	14	88

4.	Blue, flaggy sandstones, much ripple-marked, and also showing a great many fucoidal or mud marks. A rather heavy dip down stream indicates that the total thickness for the entire section is a little too great. The thickness of this zone, according to one reading, is 16 feet, and to another 26 feet. The smaller one is used in the general section	16+	74
3.	Thin-bedded, flaggy sandstones, the layers about an inch thick. This locality is where the stream has cut through a ledge, and there is a small cascade. A small but sharp anticlinal fold crosses the stream at this point, with a N. W. and S. E. axis	13	58
2.	Greenish-buff (when wet), coarse-grained, friable sandstone, which lithologically is like the Cussewago. The top of this zone is at the lower end of the cut below the cascade, and the base a little above the road, one-half mile south of Wick	25	45
1.	Covered to level of Pymatuning Creek	20	20

In the above section all of the sandstone from the base of zone No. 2 to the top of zone No. 7 apparently belongs in the Berea formation. The total thickness of these zones is 83 feet; but on account of the length of the section, $1\frac{1}{4}$ miles or more, the slow rise of the stream and the dip down stream in at least a part of the section it is probable that this amount is somewhat too great.

According to the barometer the top of the Berea sandstone south of Lindenville is 55 feet higher than in the run north of the Wm. Clark house one-half mile north of Williamsfield P. O. on the eastern side of Pymatuning Creek. Lindenville is about $3\frac{1}{2}$ miles to the southwest of the Hubbard locality which gives a southwest dip of 15.7 feet per mile.

A stream two miles south of Wick and just south of a cheese factory, near the southern line of Wayne Township, gives a partial section of the Berea formation. The lowest outcrops in the stream are to the east of the highway and the highest are found a quarter of a mile or more to the west of it. The section is as follows:

Section Near Southern Line of Wayne Township.

No.		Thickness. Feet.	Total thickness. Feet.
7.	*Berea formation.* Highest outcrop seen on stream, which consists of about 6 inches of rather fine-grained, buff, quartz sandstone. Higher, the run apparently does not cut through the soil to the bed rock	$\frac{1}{2}$	$43\frac{1}{2}$
6.	Covered interval	5+	43
5.	Thin-bedded, bluish-gray sandstone, composed of rather fine grains of quartz sand, which shows more or less cross-bedding; some of the layers are ripple-marked and the upper part of the zone splits into layers one-half inch or less in thickness. Factory spring apparently fed from this zone	15	38

No.		Thickness. Feet.	Total thickness. Feet.
4.	Zone of bluish-gray shales to shaly sandstone, in which most of the shales are arenaceous	$3\frac{3}{4}$	23 –
3.	Massive, coarse-grained, quartz sandstone, which is shown on bank of creek below farm buildings. At this locality it is 14 inches thick and has been quarried in a small way for local use. In the next stream to the north, it was quarried to a sufficient extent to furnish all the stone for the house on that farm. On the bank below the massive sandstone is shown the following section: Soft, thin, argillaceous shale 7 in. Shales and alternating layers of sandstone an inch± in thickness, with a total thickness of 2 ft. 2 in. Mostly argillaceous, grayish to buff shales, the coarser layers of which are finely arenaceous, 2 feet to bed of stream; making a total of 4 feet 9 inches from the base of the massive sandstone to the bed of the run	$1\frac{1}{6}$	$19\frac{1}{6}$
2.	A short distance down the stream is a bank from 8 to 9 feet high, composed of thin-bedded to shaly sandstone, with some rather fine-grained shales. This zone does not differ lithologically from some of the Bedford; still there are zones of shale in the Berea toward Cleveland (as in Stebbins Gulch), which are in the upper part of the formation, and yet resemble the Bedford formation lithologically. This bank is on the southern side of the run only a few rods above the highway	8+	18
1.	Partly covered interval; but a few rods below the highway are outcrops of thin-bedded, ripple-marked, bluish-gray sandstone, composed of grains of fairly coarse quartz sand. Below this point the bed rocks are apparently not shown	10	10

Orwell Well.—Orwell Township is the second one in the same tier of townships directly west of Wayne. A well was drilled in the winter of 1902-03 in the eastern part of the township on the John R. Warren farm, about $1\frac{1}{2}$ miles directly east of East Orwell (railroad station), and only a short distance west of Rock Creek. The barometer made the mouth of the well 55 feet lower than the railroad at East Orwell, which indicates that it is 855 feet above sea level. Rock Creek is about 8 feet lower than the derrick floor; but the stream is sluggish and the valley marshy at this locality. The following record of this well was furnished by Mr. Calvin Reeves, of Orwell:

Record of Orwell Well.

Depth.	
0′	Drift
146′	Gravel
	Water cased off at 208 feet "Erie shale"
1500′	Black shale
	Between 1700 and 1800 feet, top of Devonian limestone
2008′	Gray and white pumice-like, soft sandstone, which is from 80 to 100 feet in thickness Some oil from this sandstone Below a hard limestone, which went to 2300 feet
2300′	Gray, white and black sandstone The black and mixed colored sandstone soft and porous. More oil in this sandstone than in the upper one
2325′	Bottom of well in the mixed sandstone

The interesting thing shown in the above record of Mr. Reeves is that in the Monroe or synchronous formation in eastern Ohio there are two sandstones which in the Orwell well are about 200 feet apart.

Rock Creek Section.—Rock Creek flows northerly across the eastern part of Orwell and Rome townships and then turning westerly across the southern part of Morgan Township enters the Grand River. In Rock Creek village, and for some distance above, this stream is more or less completely bordered by rocky banks. Above the Ashtabula Pike bridge in Rock Creek, which was built in 1832, the rocks consist mainly of blue shales, some of them argillaceous, but more are arenaceous; in addition there are layers of bluish-gray sandstone, some of which are a foot thick. The shales form a larger proportion of the total thickness of the rocks than is the case in outcrops of the Chagrin formation in Pierpont and Monroe townships to the northeast, which will be described later on in this bulletin. The sandstones as a rule and the shales to a greater or less extent weather to a rusty color. There are a number of small anticlinal folds in this part of the creek's course and one fault with a throw of a foot or a little more. Some of the sandstone layers also show ripple-marks. Fossils are rare; an occasional specimen of *Liorhynchus*, *Camarotœchia* and two or three other genera comprising all that were found during an hour's search. The complete list is as follows:

1. Camarotœchia contracta Hall ________________________________ (c)
2. Liorhynchus mesicostale Hall ________________________________ (r)
3. Spirifer disjunctus Sowb. __________________________________ (rr)
   Internal impressions poorly preserved but apparently showing plications.
4. Productella sp. ____ (rr)
   Very imperfectly preserved.
5. Dalmanella tioga (Hall) Wms. var. elmira Wms. _______________ (rr)
   Internal impression of dorsal valve.
6. (?) Cryptonella sp. or perhaps Centronella sp. ________________ (rr)
   Fragment of specimen, but showing beautifully punctate shell structure.

Some of the sandstone layers have large numbers of so-called fucoid stems, especially on the upper surface. These rocks are lower in the Chagrin formation than those in which *Camarotœchia orbicularis* Hall and *Spirifer disjunctus* Sowb. are common, although Professor Cushing has reported *Spirifer disjunctus* Sowb. from below the railroad station on Rock Creek.

Sugar Creek enters Rock Creek from the east in the northeastern part of Rome Township. On Rock Creek below the junction of these two streams blue shales and bluish-gray sandstones are exposed, the sandstones apparently not as thick as those farther down the creek in Rock Creek village. Fossils are apparently rare in this portion of the formation since only a few were seen; but a good specimen of *Camarotœchia orbicularis* Hall was collected. In this part of the stream the Chagrin forms low banks, above which is drift, making some of the banks rather high.

Jefferson and Austinburg Townships.—These two townships in the northern central part of Ashtabula County underlain by the Chagrin formation are of some additional interest because of the natural gas field located near the township line. The principal stream of Jefferson Township is Mill Creek, which rises to the southeast near Leon, and after crossing Dorset, Denmark and Jefferson townships, enters the Grand River near the southern line of Austinburg Township.

On the north and west bank of Mill Creek at the eastern end of Eaglesville in the southern part of Austinburg Township are exposures of the Chagrin formation from 15 to 20 feet in height. These are mainly blue argillaceous and arenaceous shales alternating with an occasional thin sandstone. There are, however, in the bed of the creek some thicker layers of sandstone reaching a thickness of 6 inches or more, which are shown to best advantage in the lower and most conspicuous anticlinal fold. It is not far across this fold; but its limbs are rather steep and its axis is about N. 25° E. There are also some other smaller folds and rolls farther up the creek. At one place the rocks have been much crushed so that some of the layers are dipping at a very high angle and on the bank is a slip forming a fault with small throw.

The shales weather to a rusty color, but not red as stated by Read.[1]

Fossils occur rather generally in these rocks, but they are not common except in certain layers, and in one of these the shells are so abundant that it is somewhat calcareous. The most common species in the shales in the bed of Mill Creek, at the eastern end of Eaglesville, are *Camarotœchia contracta* Hall and *Liorhynchus ohioense* n. sp. The following species were collected from the rocks along the creek at this locality:

1. Camarotœchia contracta Hall ---------------------------------- (c)
   Some of the specimens have only 2 or 3 plications in the sinus, with 4 on the fold, 2 of which are strong. The specimens have about 16 or 17 plications on a valve (Hall's description said from 16 to 20) and in general they are rather more rounded than on New York specimens of this species, although on some of them they are somewhat angular. The Eaglesville specimens were compared with some of the types of this species in the New York State Museum, and there appears to be no doubt as to their specific identity.
2. Camarotœchia orbicularis Hall -------------------------------- (r)
   Specimens have 22 or more rather rounded plications, with the general outline of this species. It is to be recalled that Hall wrote that this species "presents many of the characters of the larger and more robust forms of *R.* [*C.*] *contracta*."[2]
3. Reticularia præmatura (Hall) Schuchert --------- -------------- (rr)
   Compared with authentic specimens of this species at Cornell University, and with type specimens in the New York State Museum.
4. Liorhynchus ohioense n. sp. ----------------------------------- (c)
   Specimens with 2 or 3 broad, rounded plications in the sinus, which do not bifurcate, or only near the umbo, and with generally a few rather indistinct ones on the sides. These specimens do not have as many plications as *L. mesicostale* Hall; they are broader and do not divide like those of that species. Neither are they *L. sinuatum* Hall of the Ithaca and Chemung formations, which has much finer and more numerous plications on the sinus and fold. Some specimens show faint plications on the sides. The originals of figs. 13–17, pl. 57, Vol. IV, Pal. N. Y., of *L. sinuatum* were studied in the American Museum. The Ohio specimens resemble considerably medium sized ones from the Ithaca formation at North Norwich, N. Y., which were labeled by Hall *L. mesicostale*, and are in the American Museum. The plications on the Ohio specimens, however, are broader and not so angular. There is also a difference in general appearance between the Ohio specimens and *L. mesicostale*, fully as much as between a good many described species.
5. Liorhynchus mesicostale Hall ---------------------------------- (rr)
   There are occasional specimens with the proportions, outline

[1]Geol. Surv. Ohio, Vol. I, p. 486.
[2]Pal. N. Y., Vol. IV, p. 352.

and dichotomous plications of this species. One specimen with rather small plications has 7 in the sinus, with 6 or 7 on the sides, all of which are conspicuously dichotomous in their upper part, as stated in Hall's description and shown in the American Museum on the originals of figs. 23 and 25 of pl. 57, Vol. IV, Pal. N. Y. The fineness of the plications and their extent over the sides of this specimen suggest *L. laura* Billings, of the Marcellus and Hamilton. It closely resembles, however, small specimens in the American Museum, from the Chemung of Bath, Steuben County, N. Y., which were labeled by Hall as *L. mesicostale*. The Eaglesville specimen has more plications on the sides than the large type specimens of this species. The smaller, or medium sized ones, however, from Bath, N. Y., have bifurcating plications on each side of the fold and sinus, which extend nearly to the lateral margins of the shell.

6. Grammysia sp. -- (rr)
   Crushed and distorted specimen.
7. (?) Edmondia sp. -- (rr)
8. Fish bone, fragment -- (rr)

A loose block in Mill Creek at this locality contained a large number of more or less crushed, but clearly marked specimens of *Liorhynchus newberryi* Hall. The locality for this species was given as Kelloggsville, Ashtabula County, Ohio, in the Erie shales. The locality is given as above by Schuchert; but the horizon as Waverly,[1] which is apparently in error, since Kelloggsville is 15 miles northeast of Eaglesville and considerably lower stratigraphically in the Erie shales (Chagrin) than the Mill Creek horizon at Eaglesville.

This locality is about 215 feet lower than the Court House in Jefferson according to the barometer. The Eaglesville locality is barometrically 200 feet lower than the loose Cleveland shale on the highway south of Trumbull, to the west of Grand River. These outcrops are estimated by Professor Cushing as about 100 feet lower stratigraphically than those already described in Rock Creek.

Below these shales and sandstones, as shown farther down the creek, are some 35 feet of soft bluish argillaceous shales with occasional layers of finely laminated, micaceous sandstones. The upper portion of these shales contains a few poorly preserved fossils of which *Liorhynchus mesicostale* Hall (?) and *Camarotœchia contracta* Hall are the most common.

On Mill Creek, two miles north of Jefferson, are exposures of the Chagrin formation which begin some rods below the railroad bridge, and continue above it with fairly continuous outcrop for a distance of one-half mile or thereabouts. Below the railroad bridge thin calcareous layers which contain large numbers of *Liorhynchus clarkei* n. sp. alter-

[1]Bull. U. S. Geol. Survey, No. 87, p. 238.

nate with blue shale. There are also some layers of sandstones both below and above the railroad bridge, some of which are ripple-marked and others contain numerous fucoid stems. Professor Cushing estimated this locality as 25 to 30 feet higher stratigraphically than the one at Eaglesville. The topographic map apparently makes the horizon below the railroad bridge about 70 feet higher than Mill Creek at the eastern end of Eaglesville; but it is 4 miles farther north and if Professor Cushing's estimate of a southerly dip of 15 feet per mile is not too great, then the stratigraphic elevation is apparently less than 25 feet, perhaps not more than 10 or 15 feet. In the limestone below the railroad bridge at this locality, the following species were collected:

1. Liorhynchus clarkei n. sp. ---------- (a)
   These specimens have about the size of *L. mesicostale* Hall; but the plications cover the sides and are about as conspicuous as on the fold and sinus, while the figures and descriptions of *L. mesicostale* give the sides as smooth or "obscurely marked by low obsolete folds." In *L. newberryi* Hall and Whitfield the shell is rather larger and covered by folds, but they are rather sharper than on these specimens, which appear to be intermediate between these two species. It has probably generally been called *L. mesicostale* Hall. Part of the specimens resemble considerably fig. 25, of pl. 11, 23d Ann. Rep. N. Y., State Cab. Nat. Hist., which is stated to have "coarser plications, especially in the mesial depression" than the other specimens figured.
2. Camarotœchia contracta Hall ---------- (a)
3. Spirifer disjunctus Sowb. ---------- (r)
4. Productella lachrymosa (Con.) Hall ---------- (rr)

From the rocks a short distance above the railroad bridge, the the following species were obtained:

1. Camarotœchia contracta Hall ---------- (c)
2. Chonetes setiger Hall ---------- (c)
3. Chonetes sp. ---------- (r)
   Larger and more gibbous specimen.
4. Reticularia præmatura (Hall) Schuchert (?) ---------- (rr)
5. (?) Platyceras sp. ---------- (rr)
6. Productella sp. ---------- (rr)
7. Leptodesma cf. longispinum Hall ---------- (rr)

Some rods above the railroad bridge is a layer of somewhat calcareous sandstone, about one foot thick, containing great numbers of *Spirophyton* impressions. One-fourth mile above the railroad bridge a blue crystalline limestone is shown in an anticlinal fold in a cliff on the northern side of the stream, which contains specimens of *Syringothyris.* Farther up the creek and 35 feet higher than the *Liorhynchus*

layer below the railroad bridge are calcareo-sandy layers, some of which are very hard blue limestone, and sandstones which contain fossils, especially *Syringothyris*. This horizon with *Syringothyris* is below the one in which the fairly abundant *Spirifer disjunctus* Sowb. fauna occurs.

Some part of the locality just described contains the section which Professor Cushing numbered 1,058 A, and described as located "about two miles north of Jefferson and 80 feet below the railway station there." His description of the rocks and his list of fossils are as follows:

"A limestone from 6 inches to 1 foot thick is here exposed just above the stream, capped by 15 feet of blue shales. The limestone is gray with a slight bluish tint, somewhat crystalline, very hard when fresh, and gradually runs into micaceous sandy shales, above and below. In color and appearance it strongly resembles the Meadville limestones, higher in the series, but it is more crystalline, and with a somewhat greater proportion of soluble matter. It has been somewhat used as a building stone for rough work in Jefferson. It is very fossiliferous, and the fauna is unique." Then the following species are listed:

"1. Syringothyris textus var. chemungensis var. nov.
2. Grammysia communis (?)
   Between G. communis and G. hannibalensis.
3. Platyceras sp.
4. Rhynchonella [Camarotœchia] contracta
5. Orthis vanuxemi
6. Leiorhynchus multicosta
7. Leptodesma sp. like L. potens
8. Sanguinolites sp.
9. Bellerophon sp.
10. Productella sp. like small P. speciosa
11. Lingula sp.
12. Crinoid stems.

"The first four forms comprise the bulk of the specimens, the first far outnumbering all the rest. The Leiorhynchus occurs where the limestone is shading into the sandy shales, and does not occur in the limestone proper. The Orthis is occasional, and the remaining forms rare. The fauna is a peculiar one in the assemblage of species, the first three forms being confined to this stratum as far as I have been able to determine. The occurrence of Syringothyris in the midst of a Chemung fauna is especially noteworthy. It is overlaid by at least 100 feet, and probably by 250 feet of shales carrying distinctly Chemung faunas."[1]

Professor Cushing has since informed me that most of the excellent specimens of *Syringothyris*, which he has from this locality, were collected by Prof. Samuel G. Williams from blocks of the limestone which had been hauled into Jefferson for building stone. Some of these stones

[1]From MS. article by Professor Cushing.

were used by Mr. E. H. Fitch and Mrs. Fitch wrote that they came from Mill Creek on the Perry farm. Professor Cushing stated, however, that he found some specimens in the rocks on Mill Creek, so that he is confident that its correct horizon was located.

There appears to be no question as to the specimens collected by Prof. Samuel G. Williams belonging to the genus *Syringothyris*. They have the cardinal area and punctate shell structure of this genus, while one specimen shows the outline of the characteristic tube or syrinx somewhat like figure 34 of plate XXV, Palæontology [New York], volume VIII, part II. Several of these specimens were also shown to Dr. John M. Clarke and Prof. Stuart Weller, who unhesitatingly referred them to *Syringothyris*. Furthermore, among the specimens collected by the writer at this locality, as already mentioned (p. 761), are several internal impressions which show a part of the split tube or syrinx. These specimens were collected from the outcrops on the bank of Mill Creek ¼ mile above the railroad bridge, so that there is no question as to their occurrence at this locality. Some of them were sent to Dr. Edward M. Kindle, who wrote as follows:

"They undoubtedly represent *Syringothyris*. It is something of a surprise to me to learn that this genus actually occurs in the Chagrin as your collections indicate. It seems to me that a more thorough and exhaustive study of that troublesome area in northwestern Pennsylvania and southwestern New York than has yet been made will be required before we can decide just what significance to attach to this occurrence of *Syringothyris* * * * .

"The specimen which you sent from Professor Cushing's collection I think also shows a syrinx."[1]

Since the genus *Syringothyris* is often listed as confined to the Mississippian this occurrence of the genus on Mill Creek, north of Jefferson, may be used as an argument supporting the reference of those deposits to the Mississippian. It is to be recalled, however, that Simpson described the species *Syringothyris randalli* from specimens collected near Warren and at Union City, Pa., in rocks that he called Chemung.[2] The rocks near Warren in which this species was collected in association with *Spirifer disjunctus* Sowb., apparently belong in the Conewango formation as described by Mr. Butts, which in age he calls Devono-Carboniferous.[3] He has also listed both of these species from zone No. 3 of the Oswayo formation of the Olean quadrangle in New York, which he referred to the Subcarbonic.[4]

Dr. Girty thinks that the form which Simpson described as *Syringothyris randalli* "almost certainly belongs to the form commonly re-

[1]Letter of January 19, 1912.
[2]Trans. Am. Phil. Soc., n. ser., Vol. XVI, 1889, p. 442.
[3]Warren folio, No. 172, Geol. Atlas U. S., 1910, library ed., pp. 3-5.
[3]N. Y. State Mus., Bull. 69, 1903, p. 995.

ferred to *Spirifer disjunctus* in the Warren area."[1] He distinctly states, however, that *Syringothyris* does occur with *Spirifer disjunctus* at this locality and horizon.[2]

Recently, however, Professor Schuchert has reported that specimens of *Cyrtia occidentalis* Swallow from the Callaway limestone at Bellamy Springs, Callaway County, Missouri, "are unmistakable individuals of *Syringothyris* * * * . This limestone is here the basal member of the Devonian invasion, and appears to be either of late Middle or early Upper Devonian time. * * * *Syringothyris*, therefore, originated in the Cordilleran sea during the later Devonian and not in the Atlantic province as the writer heretofore held, but it was not a conspicuous member of any fauna until Mississippian time."[3]

The Jefferson, Ohio, collection was studied by Professor Cushing under the direction of Prof. Henry S. Williams at Cornell University, and twenty-five years later Professor Williams when in Cuba wrote as follows concerning the age of the rocks containing these specimens of *Syringothyris*:

"I, of course, cannot go into details without my notes. But the question you ask about Syringothyris in the Devonian in Ohio and Pennsylvania depends upon the interpretation of the horizon. There are several cases I have seen in which I now think the horizon is Devonian, which at the time the collections were made I regarded as Carboniferous chiefly upon the evidence of the appearance of that genus which then was supposed to occur never below the Carboniferous (i. e. Mississipian).

"In reviewing the subject you will have to take this fact into consideration."[4]

Still farther up Mill Creek below the first north and south road crossing it, and according to the topographic map some 15 feet higher than the last locality, are bluish arenaceous and argillaceous shales, alternating with irregular layers of bluish-gray sandstone. The upper portion of the bank is composed of drift. There are also some small but rather sharp anticlinal folds shown at various localities from near the railroad bridge on up the stream. Specimens of *Camarotœchia*, *Chonetes*, *Dalmanella* and a few other imperfectly preserved shells were found.

The complete list of species collected at this locality is as follows:

1.	Camarotœchia contracta Hall	(c)
2.	Chonetes setiger Hall	(c)
3.	Dalmanella tioga (Hall) Wms. var. elmira Wms.	(r)

[1] Jour. Geology, Vol. XIX, 1911, p. 550.

[2] The exact wording is as follows: "*S. randalli* occurs at the locality and horizon of the classic association of Syringothyris with *Spirifer disjunctus*." Loc. cit.

[3] Am. Jour. Sci., 4th ser., Vol. XXX, Sept. 1910, p. 223.

[4] Letter of November 8, 1910.

The specimens are larger than those in the shales farther west, as in Chippewa Creek, etc., but they appear to be nearer this variety than any other species. One specimen is 23.4 mm. wide and 21.7 mm. long.

4. Dalmanella tioga (Hall) Wms. (rr)

One specimen with about the proportions of this species, since it has a width of 27.6 mm. and a length of 22 mm. Fig. 22 of pl. 8. Vol. IV, Pal. N. Y., is 29 mm. wide and 20 mm. long.

5. Syringothyris texta (Hall) var. chemungensis Cushing (?) (rr)
6. Schizophoria striatula (Schlotheim) Hall and Clarke (rr)
7. Grammysia cf. undata Hall (rr)
8. Leptodesma cf. longispinum Hall (rr)

One and one-fourth miles farther up the creek at the covered bridge north-northeast of Jefferson, both below and above the bridge, are low banks of bluish arenaceous shales with some layers of thin irregular sandstones. These rocks contain some poorly preserved fossils; but they are not generally abundant and it is not an especially favorable locality for collecting. A few specimens of *Spirifer disjunctus* Sowb. were obtained while *Camarotœchia contracta* Hall is the most abundant species. The coarse layers of shale and irregular sandstones contain numerous fucoidal markings. Above the bridge is an outcrop of from 5 to 10 feet and in one layer of bluish shale a good many specimens of *Camarotœchia contracta* Hall were collected.

At this locality the following species were obtained:

1. Camarotœchia contracta Hall (a)

There are several specimens in various states of preservation with 16 to 18 or 20 plications, which vary from angular to rounded, with 2 or 3 in the sinus and about 4 on the fold. Part of these specimens were compared with types of this species in the New York State Museum, and there is no doubt of their specific identity.

2. Camarotœchia stephani Hall (c)

A clearly preserved ventral impression has 4 plications in the sinus, with about 8 on each side. This one, and similar specimens, after comparison with types of *C. stephani* Hall and *C. eximia* Hall in the American Museum, are referred to the first mentioned species. On the other hand, there are specimens with from 22 to 28 rather angular plications, which perhaps in general agree more nearly with the latter species. One of these has about 4 plications in an indistinct sinus, with 10 on each side of the valve and it resembles considerably a flattened form of *C. eximia.* These specimens have not been listed as distinct from *C. stephani,* since it is not altogether certain that they belong to *C. eximia*

3. Liorhynchus ohioense n. sp. (c)

Some 12 rather large gibbous specimens were collected, which have 2 or 3 plications in the sinus and 2 or more somewhat indistinct ones near it. A dorsal valve has 2 strong pli-

cations down the center, a less conspicuous one on each side, and then 2 less distinct ones, grading down into the smooth lateral surface of the shell. In general the plications are broader, as well as fewer, than those of *L. mesicostale* Hall.

4. Spirifer disjunctus Sowb. .... (rr)
5. Lingula sp. .... (rr)
   Broken specimen; front of shell is wanting.

This locality is barometrically about 90 feet lower than the Court House in Jefferson, or 125 feet higher than the locality at the eastern end of Eaglesville. The topographic map makes it about 100 feet higher than the Eaglesville locality, and since it is 2½ miles farther north, if Professor Cushing's estimate of a southerly dip of about 15 feet per mile be correct, then stratigraphically it is only about 65 feet higher.

Banks of rock occur on Mill Creek at various places as it is followed up across the southeastern part of Jefferson Township and southwestern part of Denmark Township into Dorset Township. For some distance after entering the latter township no outcrops of older rocks were noted; but finally both below and above the dam on Mill Creek, a short distance below the Lake Shore and Michigan Southern Railroad bridge, are rock ledges. This locality is about 5½ miles farther up the stream than the covered bridge mentioned above, some 55 feet higher according to the topographic map and 1¼ miles northwest of the village of Dorset. The dam is located but a few rods below the railroad bridge, and blocks of bluish-gray to light gray sandstone are frequent in the stream for some distance below it, many of which are fossiliferous. These light gray to blue micaceous sandstones have the lithologic appearance of many of the similar thin-bedded sandstones in the Chemung of New York. At the eastern end of the dam about 10 feet of rocks is shown in the creek bank, which consist principally of blue argillaceous and arenaceous shales with occasional layers of bluish-gray sandstone which are rusty when weathered. These layers contain some fossils, and from the outcrop and the loose blocks of sandstone in the stream below a number of species were obtained. The most abundant one is *Spirifer disjunctus* Sowb., but a number of specimens of *Euomphalus* (*Straparollus*) *hecale* Hall were seen, and also several poorly preserved ones of *Cyrtia alta* Hall. Above the dam the top of the rock bank is 5 feet or more higher than the top of the shale bank at its eastern end. This higher bank is composed of shales and sandstones, while a sandstone layer near the top, in places about 1 foot thick, is fossiliferous. The complete fauna obtained at this locality is as follows:

1. Spirifer disjunctus Sowb. .... (a)
2. Cyrtia alta Hall .... (r)
   One specimen shows the cardinal area, ventral and dorsal valves and toward the front of the sinus the plications are clearly shown.

3. Athyris cf. polita Hall .... (c)
   The specimens are larger than normal ones of this species and the width in proportion to the length is a little greater, and in this respect they approach somewhat *A. angelica* Hall; but do not have so deep a sinus on the ventral valve.
4. Athyris polita Hall .... (r)
   Some of the specimens smaller than above and like figures of this species.
5. Productella lachrymosa (Con.) Hall var. lima Con. .... (c)
6. Dalmanella leonensis Hall (?) .... (rr)
7. Camarotœchia orbicularis Hall .... (c)
8. Liorhynchus sp. .... (rr)
   Too imperfectly preserved for specific identification.
9. Sphenotus contractus Hall .... (rr)
   Both specimens show the fold on the post-cardinal slope.
10. (?) Grammysia cf. undata Hall .... (rr)
    Poorly preserved specimen and difficult of identification.
11. Euomphalus (Stroparollus) hecale Hall .... (c)
12. (?) Cyclonema cf. obsolescens Hall .... (rr)
    Imperfect specimen and identification is doubtful.
13. Spirophyton velum Van. (?) .... (rr)

The banks of the stream in this general region to a greater or less extent are composed of drift.

A mile to the south of the above locality and about seven-eighths of a mile to the south-southwest of Dorset, and a few rods below the bridge on the north and south highway crossing Mill Creek is a rock bank about 10 feet high. The bed of the stream at this locality, according to the barometer, is some 5 feet lower than the rocks at the top of the cliff above the dam at the locality just described. The bank is composed principally of blue argillaceous and arenaceous shales with some layers of blocky thin sandstone. A heavy layer of sandstone occurs in the bed of the stream under the bridge. The sandstones are fossiliferous and *Spirifer disjunctus* Sowb., is the most abundant species. *Cyrtia alta* Hall and *Reticularia præmatura* (Hall) Schuchert also occur.

The complete list of species collected at this locality, which is the highest fauna found in place on Mill Creek, is as follows:

1. Spirifer disjunctus Sowb. .... (c)
2. Reticularia præmatura (Hall) Schuchert .... (r)
3. Cyrtia alta Hall .... (r)
   Fairly high impressions of cardinal area of ventral valve. A poorly preserved impression of ventral valve shows plications in the sinus. One specimen of cardinal area in which the delthyrium is perforated similar to that shown in specimens of *Syringothyris* from Mill Creek north of Jefferson.
4. Strophalosia muricata (Hall) Beecher (?) .... (r)
   or
   Productella hirsuta Hall.
5. Productella lachrymosa (Con.) Hall var. lima Con. .... (r)

6. Athyris polita Hall .... (r)
7. Camarotœchia orbicularis Hall .... (rr)
8. Dalmanella leonensis Hall .... (c)
    Width of large specimen 12.8 mm., which agrees with Professor Williams' statement that this is a small shell "ordinarily not over 12 mm. wide." Twenty-one lines on the front margin of one-half of a valve and Williams says there are from 20 to 25.
9. Schizophoria striatula (Schlotheim) Hall and Clarke (?) .... (rr)
10. Schuchertella chemungensis (Con.) Girty (?) .... (r)
11. Euomphalus (Straparollus) hecale Hall .... (r)

Above this locality outcrops of the Chagrin rocks are rare on Mill Creek or its branches. About $3\frac{3}{4}$ miles southeast on the road to Leon and $1\frac{1}{8}$ miles northwest of that station on the eastern fork of Mill Creek are loose sandstones which contain specimens of *Spirifer disjunctus* Sowb. and *Productella* sp. Apparently these rocks have not been moved any considerable distance. The farmer on whose land they occur stated that about 14 feet below the bed of the draw are slate (shale) and some layers of sandstone. These were the highest fossiliferous rocks seen in the vicinity of Leon. The country from Leon north along the "old turnpike" to Steamburg Church, on the West Branch Ashtabula River, is pretty flat with few if any indications of outcrops. It is more or less marshy along the streams and their banks are composed largely of drift.

Much interest has been aroused in the geology of the Jefferson region on account of the occurrence of natural gas in considerable quantity and a small amount of oil. Two or three wells drilled in or near Jefferson have produced from one to two barrels of oil a day.

The following record of one of these wells was furnished by Mr. F. S. Jones:

Jefferson Well.

Description.	Thickness. Feet.	Total depth. Feet.
Ohio shale	1810	1810
Devonian limestone (light colored)	288	2098
White sand, called "salt sand"	13	2111
Gray rock	8	2119
Black rock	8	2127
Oil sand	13	2140[1]

Mr. Eugene Coste has furnished the writer with the following record of the Home Co. well located on the northern edge of the town of Jefferson:

[1]Also see Geol. Surv. Ohio, 4th ser., Bull. 1, 1903, p. 303, for a record of th well.

Home Co. Well, Jefferson.

Elevation 920 feet above sea level.

Description.	Thickness. Feet.	Total depth. Feet.
Ohio shales. Gray shales, the lowest 20 feet rather dark	1805	1805
Devonian limestone. Light colored limestone with a notable quantity of chert at 2010 feet	300	2105
Coarse sandstone, with some gas, oil and salt water	20	2125

The principal gas field of this region is about three miles northwest of Jefferson near the Jefferson-Austinburg township line, where nine or more wells have been drilled. The well on the Betsy Markham farm was visited while it was being drilled. The greater part of the drillings lying about the derrick were of bluish or grayish color, evidently from the Chagrin formation. Mr. E. M. Knapp, one of the drillers, gave the following record of this well:

The Markham Well.

Description.	Thickness. Feet.	Total depth. Feet.
Chagrin formation. Bluish shale	1500	1500
Black shale with brown streak	75	1575
Brownish shale	75	1650
Black shale, which is darker than the upper zone	50	1700
Devonian limestone. The limestone was reported by Mr. James Hunter as 290 feet thick	290	1990
Bottom of well in gas sand at about 2020 feet	30	2020

The most complete record of a well in this field, one drilled on the farm of Mrs. A. C. Hawks, was furnished by Walle Bros. This well was sold for $20,000.

The Hawks Well.

Elevation about 890 feet above sea level.

Description.	Thickness. Feet.	Total depth. Feet.
Chagrin formation. Gray shale	1510	1510
Black shale with brownish streak	60	1570
Grayish shale with white streak	90	1660
Black shale, which is blacker than the upper black shale zone	70	1730
Devonian limestone	100	1830
Limestone, which is cherty and somewhat sandy	150	1980
Softer rock of light gray color	40	2020
Gas sand (*Sylvania* ?) and bottom of well	10	2030

The writer saw a sample of this gas sand which came from a depth of 2,023 feet that was blown out of the well when gas was struck; pieces

of the sandstone were thrown as high as the top of the derrick. A well was visited in August, 1904, on the T. J. Stewart farm, which had been drilled three years; but where the tubing had just been pulled. The gas was not shut in so that it was freely escaping from the mouth of the well and looked like smoke. The odor of gas was noticeable in the air for some distance. Some of the wells yield oil, but gas is the important product which comes from a quartzose sandstone (Sylvania ?) in the Monroe (or Salina of the New York classification) formation.

Conneaut and Monroe Townships.—These two townships on the eastern border of Ashtabula County constitute the northeastern corner of Ohio, to the east of which are Springfield and Conneaut townships of Erie County, Pennsylvania, and Beaver Township of Crawford County, Pennsylvania. Conneaut Creek entering from Pennsylvania flows southwesterly across the southeastern part of Conneaut and the northwestern corner of Monroe townships into Kingsville Township, which lies directly west of the two townships just mentioned, where the creek makes a great bend and returns in a northeasterly course across the northwestern part of Conneaut Township, entering Lake Erie at Conneaut.

At various localities, in both Conneaut and Kingsville townships, there are fairly high shale banks bordering Conneaut Creek the highest ones perhaps occurring in the latter township. A fair one may be seen on the creek bank and in the Bessemer and Lake Erie Railroad cut where the railroad crosses the creek about one mile southwest of the central part of the town. On the opposite bank near a grist mill is another exposure, but not so good. A little farther up the stream is a considerable bend with good exposures of the shale in the banks.

On the south side of Conneaut Creek, about 6 miles southwest of Conneaut and $1\frac{3}{4}$ miles east of Kingsville, is a long bank of shale. In places it is probably 60 feet in height and is apparently composed mainly of thin argillaceous shales with alternating layers of arenaceous shale to thin sandstones. The sandstones are very thin, however, and by far the greater part of the bank is composed of shale so that as weathered there are no prominent projecting layers. The general appearance of the bank is similar to that of others farther west on the Grand and Chagrin rivers. A view of this bank is shown in the accompanying half-tone, Plate LXV, A.

A steep cliff occurs on the southern bank of Conneaut Creek, about 7 miles southwest of Conneaut and a short distance south of the Conneaut-Kingsville highway, for perhaps about one-fourth mile, which in places is probably 50 feet high. The rocks are mainly bluish shale, which is both argillaceous and arenaceous with very thin layers of sandstone. A layer from 2 to 4 feet above the creek has a tendency to form concretions which are occasionally in the form of septaria. Frequently in connection with these concretions are layers of cone-in-

cone. In some places there is simply a rapid thickening of this sandstone layer with hardly any suggestion of a concretion, just a sandstone lens. In layers of the soft shale below this concretionary one a good many specimens of *Liorhynchus* sp. were found. Some of the pieces contain a large number of specimens of this species, which is usually flattened and the shell almost gone. There are both large and small specimens of the fossils, but both probably belong to the same species. These were the only fossils found, although some little time was devoted to the search.

There are large blocks of recent conglomerate in the creek which have rolled down from the old lake shore beach which occurs just north of the creek bank.

The banks of Ashtabula River in Ashtabula and Plymouth townships also afford excellent outcrops of this portion of the Chagrin formation. Particularly good outcrops are shown in the cliffs of the river east of the city of Ashtabula and along the river for some distance above the city. From the lake shore the bed and cliffs of the river when followed to the southern limit of the city of Ashtabula give a continuous exposure of some 130 feet of these rocks. They are composed mainly of soft and fissile shales of bluish-gray color, although some of the softer ones have a greenish tint. There are also frequent layers of laminated, micaceous shales as well as of flat, somewhat calcareous concretions. In addition, in some localities are abundant more or less spherical, small nodules of iron pyrites and marcasite.

As already stated, the general appearance of these shale banks is about the same as that of the Chagrin formation on the lower courses of streams farther to the west, as for example the Grand and Chagrin rivers. Again they are very similar to those on the streams to the east in Erie County, Pennsylvania, which Dr. White referred to his Girard shales. These rocks were referred to the Erie shale by Read, who stated that "by far the largest portion of the county [Ashtabula], that shaded green on the map, is covered by the Erie shales; and they are from 800 to 1,000 feet thick, and extend far under the lake."[1] The next township to the east of Conneaut is Springfield in Erie County, Pennsylvania, which is stated by Dr. White to be "everywhere buried so deep beneath the *Drift* that the streams have seldom cut through it. Except along Conneaut Creek, at the southern township line, and at one locality on the Lake Erie Shore, I could see no rock exposures in the entire area."[2] The underlying rocks, however, are stated to "belong to the lower half of the *Chemung flags*, and to the *Girard shale*; the latter extending to the lake shore." Also "at the mouth of Crooked Creek, the top of the *Portage flags* are visible 15′ above lake level = 588′ A. T.,"[3] and on the geological map the top layers of the Portage

[1]Geol. Surv. Ohio, Vol. I, 1873, p. 486.
[2]Second Geol. Surv., Pa., Q^4, p, 256.
[3]Loc. cit.

are represented as rising above the lake level a short distance east of Raccoon Creek and then bordering the lake shore to the northeast until it passes into New York, where the top is said to be 475 feet above the level of Lake Erie.[1] In reference to the age of this formation Mr. Luther, of the New York Geological Survey, reported Chemung fossils in Twelve Mile Creek, about 30 feet above the lake level,[2] near Northeast, a village near the northeastern corner of Erie County. Also the last "Geologic Map of New York," prepared under the direction of Dr. Merrill and published in 1901, shows the top of the Portage as passing below lake level before reaching Pennsylvania, succeeding which is the Chemung formation, which is shown as covering the remaining portion of extreme southwestern New York.

Girard Township lies next to the east of Springfield Township, in which are the typical exposures of the Girard shale, especially as shown on Elk Creek, above the village of Girard. This shale was named and described as follows, by Dr. White: "A succession of ashen-gray and bluish shales, with only now and then a thin sandy stratum; no fossils except *fucoids*; thickness, say 225′; * * * forms the Drift-covered rock-surface of western Erie county facing the lake, and is finely exposed in every ravine which descends northward from the Great Divide; but especially along Elk creek, above Girard. Seen at a distance, its bluff-slopes look remarkably like the Bowlder clay of the Drift, and sometimes like vast banks of gray coal-ashes.

"Its base, or lowest level, is at lake-level at Raccoon creek, near the Ohio State line, and 475′ above lake-level at the New York State line.

"I have never found a single fossil shell in it, at hundreds of exposures examined; but *fucoid casts* are very abundant."[3]

On the legend of the "Geological Map of Crawford and Erie Counties" the Girard shale is described by Dr. White as follows: "Ashen gray Shale quite homogeneous throughout, with very few gritty layers and totally destitute of all animal remains, constituting the transition series between the Portage and Chemung."[4]

Under the description of Girard Township, Dr. White stated that "the *Girard shales* are exposed all along Elk creek as a series of bluish or ashen-gray shales, remarkably uniform, and singularly destitute of any organic remains save *Fucoids*, which occur in abundance.

"Very few sandy layers occur in the series, which consists of finely laminated slate and clay layers. These line the streams in vertical cliffs, and from a distance look like huge heaps of gray coal-ashes."[5] Finally, Dr. White stated in describing the outcrops on Elk Creek that:

[1]Ibid., p. 119.
[2]N. Y. State Mus., Bull. 69, 1903, p. 1028.
[3]Second Geol. Surv., Pa., Q^4, pp. 118, 119.
[4]Ibid., sheet 2.
[5]Ibid., p. 258.

"As we pass down Elk creek, the *Girard shale* continues to floor the stream and form cliffs along its banks until we reach Girard. Here the *Portage flags* begin to come up in the bed of the creek, and the layers of sandstone have there been quarried for a time on the land of Dr. Ealy."[1]

The writer has studied the outcrops of the Girard shale along Elk Creek twice; first, while an assistant of Prof. Henry S. Williams in 1884, and again twenty years later in 1904 in connection with field work for this bulletin.

The Lake Shore and Michigan Southern Railroad crosses Elk creek about three-fourths of a mile west of Girard station. Below the bridge, on the western bank, are fine bluish shales, which weather to an ashen color, and are near the base of the Girard. In the stream above the Lake Shore bridge are very compact, bluish, fine-grained sandstones which have a strong petroleum odor. The top of these sandstones appears in the bed of the creek and on the lower part of the bank near the mill, and they are apparently those called by Dr. White the Portage flags. On the bank above, are blue shales, with an occasional layer of sandstone an inch or more in thickness. This locality is only a short distance below the Dr. Ealy farm, where Dr. White stated the Portage flags were quarried. It was also stated that these Portage rocks consist of "thin sandstones alternating with shales, which border the lake shore all the way to the N. Y. State line. Where quarried here on the land of Dr. Ealy it is a hard, blue, fine-grained sandstone, not quite one foot thick, and covered with *Fucoidal* markings." Dr. White's Girard section, near this locality, a short distance below where the road crosses Elk Creek, and on the right bluff of the stream, is as follows:

"*Girard shales*, bluish gray	40′
Sandstone layer in bed of creek [Portage flags]	8″ to 10″ "[2]

The Girard shales lithologically are very similar to the lower part of the Chagrin formation as seen in northeastern Ohio, of which they are the eastern continuation.

The reports of Dr. John M. Clarke and Mr. D. D. Luther, of the New York Geological Survey, together with the last Geologic Map of that State, apparently show that the Girard shales are of Chemung age. It must also be recalled that in 1884, Prof. Henry S. Williams and his party studied the Girard shales at their typical locality on Elk Creek and collected fossils in them. Dr. White was unsuccessful in finding fossils in the Girard shales, for in describing a section in the southern part of this township, on a tributary of the South Branch of Elk Creek, which was referred to the Chemung, he noted a shale some 50 feet above the base of the section in which it was reported that there

[1] Ibid., p. 259.
[2] Loc. cit.

"may be seen multitudes of a shell very much resembling *Avicula fragilis* [*Lunulicardium* (*Pterochænia*) *fragile* Hall].

"*This is the lowest horizon at which I have ever found any fossils in the Chemung flags*, and as we go down the stream from this point *not a trace of a fossil animal is seen in the fine exposures of the Girard shale.*"[1] On the chart of "Meridional sections of the upper Devonian deposits of New York, Pennsylvania and Ohio" by Henry S. Williams, the Girard section is No. III, on which a Portage fauna (C^2), "the Lamellibranch stage, with *Cardiola speciosa*, etc.," is shown at an elevation of 625 feet above the top of the Genesee shale and the lowest Chemung fauna (D^4), "the stage of *Rhynchonella contracta*" is shown at an elevation of 875 feet above the Genesee.[2] The hatching of this section indicates that both of these faunas are contained in the "Portage green argillaceous shales," C^2 at an apparent elevation of 125 feet above Lake Erie and the lowest appearance of D^4 at 375 feet. The top of Dr. White's Portage flags at Girard he gave as 62 feet above the level of Lake Erie.[3] This examination of Dr. Williams' interpretation of the Girard section as given on the chart apparently shows that he considered the Girard shale as representing part of the New York Portage. The text, however, apparently does not corroborate this conclusion for he states that "the fourth stage (D^4) [of the Chemung fauna] is confined to the sections of Chautauqua [southwestern New York] and Girard, until near the termination of the Chemung deposits, when it spread eastward, and is the only stage of the Chemung fauna recognized at the eastern extreme and there only at the very termination of the marine deposits. *Spirifera disjuncta* and *Rhynchonella contracta* are almost the only species found in this upper fauna, but in the western sections (the Girard and Chautauqua) these species occur very early in the deposits, the latter having been found as low as the Portage flags of White's classification. * * * *

"The fauna which appears at the upper stage of the green shales in the Girard section (the Girard shale and upper Portage of I. C. White) is restricted to a higher and higher horizon going eastward, so that in the Chenango section [of central New York] it is the last fauna seen below the reds."[4]

In a later publication by Professor Williams, it appears to be clearly stated that he regards the lower deposits of northeastern Ohio as of Portage age. For in describing the Pennsylvania section, he stated that "after passing the Hamilton formation and the black Genesee shale, where they are recognized, there is—

"First. A series of thin bedded deposits, generally more agillaceous than sandy, constituting the blue or green shales of the Portage

[1] Ibid., p. 258.
[2] Proc. Am. Assoc. Adv. Sci., Vol. XXXIV, 1886, Chart following p. 234.
[3] Loc. cit., p. 259.
[4] Loc. cit., pp. 227, 228.

group, containing little or no iron, except in the condition of pyrites.

"Second. A series of similar shales, but of generally lighter color and weathering brown to yellow from iron oxides, and with occasional thick, massive beds of light gray sandstones, often coarse grained and in places conglomeratic, and holding petroleum in some areas. When seen on the surface they are often strongly calcareous, and generally give off a strong bituminous odor upon first fracture."[1]

Then, on considering the "Order of deposits in Ohio," Professor Williams wrote as follows: "Now, turning in the other direction [to the west of Pennsylvania, as he had just been comparing the Allegany County section of New York, and farther east], in Ohio we find a different order of strata. The first group [which is called the Portage in the Pennsylvania section], instead of being followed by the heavier and more frequent sands of the second group, is followed by a return of the condition below, black fine shales and soft greens taking the place of thin bedded shales and sands. And the whole interval of the second and third groups of the areas farther east is represented by only one, at greatest only two, of the sandy conglomerate deposits.

"The explanation of this condition of things is to be fully determined only by the fossils. I find that the first group holds a Portage fauna in the soft green shales and a Genesee fauna in the black interleaved shales. I find the second group marked by the departure of the Portage fauna at the first massive sandstones; and with the deposition of those sands of the second group, both in them and in the accompanying shales, which are more ferruginous than those below, the Chemung fauna appears."[2]

Loose pieces of stone in the valley of the South Branch Ashtabula River, about one mile south of Kelloggsville, in the western part of Monroe Township, contain fossils in considerable abundance. Some of the blocks are composed somewhat largely of fossils as *Camarotœchia* and in addition *Liorhynchus* (large one), *Spirifer disjunctus*, *Cyrtia*, *Productella*, *Chonetes*, *Dalmanella*, etc., were found. These blocks were undoubtedly washed down by the stream from layers in which they are in place somewhat higher and farther to the south. The locality where they were collected is some 250 feet higher than Conneaut Creek at the mill southwest of that town. Unfortunately the entire collection of fossils from these two townships was lost during its transportation to Columbus, Ohio, in 1902.

Shale bank some 25 feet high on the east side of the West Branch Ashtabula River, about two miles south of Kelloggsville, in the western part of Monroe Township. This bank is a little farther up the creek than the school-house on the farm of J. C. Usher, and is composed mainly of either argillaceous or arenaceous shales, with thin

[1]Bull. U. S. Geol. Survey, No. 41, 1887, pp. 19, 20.
[2]Ibid., p. 20.

layers of thicker arenaceous shales to thin laminated, micaceous sandstones. Occasionally there is a thicker layer which is somewhat calcareous from numerous shells and more infrequently there is one an inch or two thick, which is a genuine firestone from the great number of specimens of *Spirifer disjunctus* Sowb. that largely compose it. Such a layer occurs in the upper part of the bank above the small run, and more impure ones farther up the stream. The most abundant fossils are *Spirifer disjunctus* Sowb. and *Camarotœchia contracta* Hall, which in certain zones are thick. They are both, however, found in the soft, argillaceous shales of this bank. There are also little lenses of sandstone in the midst of the shales which contain numerous specimens of *Spirifer disjunctus.* These shales vary in color from bluish to greenish-gray and gray. The harder layers form slight projections in the surface of the shale bank which may be seen for some distance. The level of the creek at this locality, barometrically, is 275 feet higher than Conneaut Creek at the mill, southwest of Conneaut. The lithologic characters of these rocks, together with the firestone layer, recalls strikingly the general appearance of the Chemung rocks in Chautauqua County of southwestern New York, as for example, the outcrops that may be seen on Little Chautauqua Creek in that county.

The West Branch Ashtabula River on the east and west Monroe-Pierpont township line highway near the southwest and northwest corners of the two townships, has a rock bottom. This locality is $2\frac{1}{4}$ miles west of Fords Corners, 5 miles from Pierpont, about 14 miles from Conneaut, and 15 miles northeast of Jefferson. The rocks are bluish-gray, somewhat irregularly bedded sandstones, which on weathering are usually very rusty in color from iron, some layers 10 inches in thickness, which have been quarried for barn foundations, alternating with blue arenaceous shales. The upper part of some of the sandstones contains large numbers of *Spirophyton* impressions and numerous grains of iron pyrites. There is a strong local dip at this place of from 10° to 15° E. of S.

The sandstones below the bridge as a rule vary from 4 to 6 inches in thickness; but one zone composed of several layers is 15 inches thick. On two loose blocks rather imperfect ripple-marks were noted as well as on some layers in place. The sandstones contain numerous specimens of fucoid stems as well as impressions of *Spirophyton.* In some layers of the blue shale exposed in bed of stream a few rods below the bridge, are abundant specimens of *Camarotœchia orbicularis* Hall. A few specimens of *C. contracta* Hall and either *C. eximia* Hall or *C. stephani* Hall were also found, as well as one of *Spirifer disjunctus* Sowb. in a loose block. The stream was followed until, according to the barometer, it was 15 feet lower than the bridge; but these lower rocks apparently have but few fossils aside from the *Spirophyton* impressions and fucoid stems.

The complete list of species collected at this locality is as follows:

1. Camarotœchia orbicularis Hall .... (a)
2. Camarotœchia contracta Hall .... (r)
3. Camarotœchia stephani Hall (?) .... (rr)
4. Spirifer disjunctus Sowb. .... (rr)
5. Productella hirsuta Hall .... (rr)
   Concentric lines and spines appear to agree with this species.
6. Spirophyton sp. .... (rr)

A calcareous layer some little distance above the bridge contains a large number of specimens of *Camarotœchia orbicularis* Hall, as well as a few of *Strophalosia muricata* (Hall) Beecher.

In addition, specimens of the following species were obtained:

1. Camarotœchia contracta Hall .... (c)
2. Spirifer disjunctus Sowb. .... (rr)
3. Productella boydi Hall (?) .... (c)
   The surface of the shell is marked by elongated ridges which probably support spines as stated in the description of this species; but the ventral valve does not show the medial depression and the cardinal margins are not rounded so that the cardinal line is less than the width of the shell.

Some of the thin layers of sandstone are a very pleasing bluish-gray to a light dove color. Small anticlinal folds cross the stream.

In the bed of East Branch Ashtabula River, which crosses the Monroe and Pierpont township road, about half way between the last described locality and Fords corners, the rocks are mainly bluish, irregular, thin-bedded sandstones, alternating with shales and very similar in lithologic appearance to those on West Branch. Numerous specimens of fucoid stems and *Spirophyton* occur in the upper surface of certain sandstone layers, as well as grains of iron pyrites. Some of the more even-bedded, light blue sandstone layers above the bridge contain a considerable number of specimens of *Spirifer disjunctus* Sowb.; also specimens of *Camarotœchia orbicularis* Hall, *C. contracta* Hall, *C. eximia* Hall (?), a few of *Strophalosia muricata* (Hall) Beecher, of Pelecypods as *Liopteria* sp. and a single specimen of a very large *Orbiculoidea.*

The complete list of species collected at this locality from both below and above the bridge is as follows:

1. Spirifer disjunctus Sowb. .... (a)
2. Camarotœchia contracta Hall .... (c)
3. Camarotœchia orbicularis Hall .... (c)
4. Dalmanella tioga (Hall) Wms. var. elmira Wms. .... (c)
5. Strophalosia muricata (Hall) Beecher .... (r)
   Some of the ventral valves are more gibbous than most specimens; but show the six spines on the hinge line on each

side of apex. Possibly they are *Productella lachrymosa* (Con.) Hall and the spines are a little below the hinge line; but it does not look as though their position is such. A dorsal valve is clearly truncate at the beak.

6. Productella lachrymosa (Con.) Hall .... (rr)
7. Romingerina (Centronella) julia Winch (?) .... (rr)
   This species was identified by Prof. H. S. Williams in the Chemung of southwestern New York.
8. Lingula sp. .... (rr)
9. Orbiculoidea alleghania (Hall) Schuchert .... (rr)
10. Mytilarca sp. .... (rr)
11. Leptodesma cf. longispinum Hall .... (rr)
12. Modiomorpha cf. tioga Hall .... (rr)
   This specimen is 46 mm. long and 24 mm. high; while the one described by Professor Hall is 50 mm. long and 24 mm. high.
13. Euomphalus (Straparollus) hecale Hall .... (r)

A small run on the farm of S. K. Swain crosses the highway 2½ miles south of Monroe Center. Above the bridge, light blue, fine-grained sandstones, alternating with blue shales are shown. Some of the sandstone layers are ripple-marked. Specimens of *Spirifer disjunctus* Sowb., *Camarotœchia contracta* Hall, *Productella,* and *Dalmanella tioga* (Hall) Wms. var. *elmira* Wms. were found. The complete list of species collected at this locality is as follows:

1. Spirifer disjunctus Sowb. .... (a)
2. Athyris polita Hall .... (a)
3. Camarotœchia contracta Hall .... (c)
4. Camarotœchia orbicularis Hall .... (c)
5. Liorhynchus newberryi Hall .... (c)
6. Liorhynchus ashtabulense n. sp. .... (c)
7. Liorhynchus mesicostale Hall .... (rr)
8. Dalmanella tioga (Hall) Wms. var. elmira Wms. .... (c)
9. Romingerina (Centronella) julia Winch. .... (rr)
10. Chonetes minutus n. sp. .... (c)
11. Productella hirsuta Hall (?) .... (r)
12. Productella lachrymosa Hall .... (rr)
   Inside of dorsal valve.
13. Euomphalus (Straparollus) hecale Hall .... (rr)

Rocks are shown in the bank of West Branch Ashtabula River, both above and below the iron bridge on the east and west road one mile north of Gould. A small, but sharp anticlinal fold occurs a few rods below the bridge, and a little farther down stream in thin-bedded sandstones are ripple-marks. This is a good locality for fossils and the following species were obtained:

1. Spirifer disjunctus Sowb. .... (a)
2. Dalmanella tioga (Hall) Wms. var. elmira Wms. .... (aa)
3. Camarotœchia contracta Hall .... (a)
4. Camarotœchia orbicularis Hall .... (c)

5.	Camarotœchia stephani Hall	(r)
6.	Athyris polita Hall	(c)
7.	Liorhynchus ohioense (?) n. sp.	(r)
8.	Chonetes setiger Hall	(r)
9.	Productella lachrymosa (Con.) Hall	(rr)
10.	Strophalosia muricata (Hall) Beecher	(r)
11.	Euomphalus (Straparollus) hecale Hall	(c)
12.	Orthoceras sp. Small form.	(rr)
13.	Lyriopecten cf. magnificus Hall A broken specimen.	(rr)

Kelloggsville, Pierpont and Jefferson are three of the localities specifically mentioned by Dr. Newberry from which fossils had been collected in the Erie shale. His complete statement is as follows:

"Kelloggsville, Ashtabula, Pierpont, Morgan, Rome and Jefferson, may be mentioned as localities from which interesting fossils have been obtained in the Erie shale. They consist of *Leiorhyncus mesacostalis, L. quadricosta, Spirifera disjuncta, S. alta,* &c., &c. With these and some others which are well known Chemung fossils of New York, are many new species. * * * * The Erie shales are the extension westward of the Chemung, and upper half of the Portage Groups of New York, here diminished in thickness, more argillaceous in composition, and so blended as to be inseparable."[1] In an earlier portion of the report in the chapter on the "Devonian System" Dr. Newberry wrote as follows concerning the fossils of the Erie shale:

"The list of species new and old which we have found in the formation is not a long one, but in some localities the individuals of some species are very numerous. Near Kelloggsville and at Ashtabula in Ashtabula county, some thin sheets of impure limestone contained in the Erie shale are not only filled but composed of the shells of a new species of *Leiorhynchus* (*L. Newberryi* Hall). In Jefferson, Morgan and Pierrepoint [Pierpont] in the same county, *Spirifer disjunctus, S. altus, Orthis Tioga, Productella speciosa, Leiorhynchus mesacostalis,* and species, probably new, of *Meristella* and *Euomphalus* are locally very abundant."[2]

Dr. Newberry described the Erie shale as follows:

"I designate by this name a group of greenish or bluish argillaceous shales which form the Lake shore from the Pennsylvania line to Avon point. The base of this series on the eastern margin of the state is below the Lake level, so we have no means of ascertaining what its precise thickness is in that vicinity."[3] On the following page, however, Dr. Newberry reported that "on the eastern border of the state, the Erie shale has a thickness of nearly 1,000 feet."

[1]Geol. Surv. Ohio, Vol. I, p. 488, f. n.
[2]Ibid., p. 166.
[3]Ibid., p. 163.

On the "Geological Map of the State of Ohio," prepared by Dr. J. S. Newberry, and published in 1879, all of Ashtabula County, with the exception of the southeastern and southwestern corners, was represented as underlain by the Erie shale; for which name on account of its preoccupation, the writer has proposed the one of Chagrin formation. In this Erie shale area was included all of the townships of Conneaut, Kingsville, Monroe, Pierpont, Jefferson and Austinburg, which have been under discussion in the preceding pages. The boundary of this formation has remained practically, if not quite, the same on all the succeeding geological maps of Ohio, which is also true of the last one published by Dr. J. A. Bownocker, in 1909, only on the legend it appears under the name of the Olentangy and Ohio shales.

To the east of the northern half of Monroe Township is Conneaut Township, Erie County, and the northern part of Beaver Township, Crawford County, Pennsylvania, and this area is represented by Dr. White on the "Geological Map of Crawford and Erie Counties" as underlain by the Chemung flags. In the description of Conneaut Township, Erie County, it is stated that "the whole township is one bed of Drift, which buries the rocks so deeply that the streams seldom cut down to the rock strata concealed beneath it. Occasionally exposures, however, show that all the hills are too low to catch the *Third Oil Sand*; and that all the surface rocks of the township are *Chemung flags*; Conneaut creek not cutting quite down to the *Girard Shale*."[1]

On the legend of the "Geological Map of Crawford and Erie Counties" Dr. White described the Chemung flags, which are given as 325 feet thick, as follows: "A succession of shales and flaggy sandstones very fossiliferous with characteristic Chemung species at upper half but all animal fossils disappearing towards the base of the series."[2]

In the chapter on the "Middle Devonian Rocks" Dr. White described the Chemung as follows: "Alternate groups of shale and sandstone; fossiliferous, especially in the upper half, with a thin *limestone layer* at the bottom; thickness say 325′; outcrop along the Lake Erie slope. * * * *

"Some tolerably massive sandstone layers occur in the upper part of the series; but no pebbles—nothing coarser than sand grains—have been noticed.

"*Fossil forms* (except *fucoids*) are wholly wanting at the base of the series; increase in number upwards; and become very abundant through the upper 175′; with numerous *spirifer beds*, two of which are specially mentioned in the section.

"*Rhynchonella contracta*, *Leiorhynchus Newberryi*, *Spirifer disjuncta*[*us*], *Spirifer mesocostalis*? *Productella hirsuta*, *Productella lachrymosa* ? *Productella Boydii*, are the common forms. *Atrypa hystrix* and many other genuine Chemung types occur."[3]

[1]Second Geol. Surv. Pa., Q^4, pp. 254,255.
[2]Ibid., Sheet 2.
[3]Ibid., pp. 117, 118.

Dr. White preferred to correlate these Chemung flags with the lower Chemung of New York, and to consider the superjacent Venango oil sand group as representing the upper Chemung.[1] Professor Lesley, however, did not accept this correlation, but apparently favored the opinion of Mr. Ashburner in correlating them with the Catskill.[2]

The Venango group was mapped as covering the central part of Beaver Township, Crawford County, Pennsylvania, which lies to the east of the southern half of Monroe Township. Under the description of Beaver Township, Dr. White stated that "the rocks exposed belong entirely to the *Venango Oil Sand group*, and near the northern line of the township the *Third sand horizon* lies within a few feet of the surface."[3] The Venango oil sand group was described by Dr. White as consisting of the following members: The Venango upper sand (First Oil Sand), 20 to 30 feet in thickness, which in Erie County consists simply of sandy deposits, "in other words sandy shales or flags occur among the finer muddy shales * * * * But in no case have I seen coarse or pebbly strata."[4] At Meadville 20 to 25 feet of sandstone flags rise out of French Creek "and are easily traceable by frequent exposures northward. * * * *

"*Productella Boydii, Aviculopecten suborbicularis, Pteronites*, sp.? and *Spirifer disjuncta* (all of them considered good Chemung types) I have collected from this horizon in my district."[5]

Next below is the Venango upper shale which consists of "*Pale blue shales*, 90′ to 100′ thick, [that] underlie the *Upper Sand* everywhere through Erie county."[6]

These shales are underlain by the Venango middle sandstone (Second Oil Sand) which is perhaps 20 feet in thickness, and it is stated that "this horizon makes little show in Erie county, being merely marked (everywhere) by a greater number of sandy shales or flagstone layers, in the mass of softer shales. * * * * Nowhere have I found it a sandstone mass, or seen it exhibit a layer of pebbles."[7]

Next below are the Venango lower shales, and it is stated that "in the interval of from 100′ to 125′ between the *Venango Middle and Lower sandstones*, lie blue, gray and brown shales, *very fossiliferous*.

"Sometimes the whole interval wears a dark colored aspect.

"*Rhynchonella contracta, Streptorhynchus Chemungensis, Leiorhynchus mesacostalis, Productella Boydii, Spirifer disjuncta*, and many other distinctively Chemung types which I could not specifically identify are scattered through the interval."[8]

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[1]Ibid., p. 117.
[2]Ibid., pp. IX–XI.
[3]Ibid., p. 210.
[4]Ibid., p. 102.
[5]Loc. cit.
[6]Ibid., p. 103.
[7]Loc. cit.
[8]Ibid., p. 104.

Finally, constituting the base of the group is the Venango lower sandstone (LeBœuf conglomerate, Panama conglomerate [of New York], Third Oil Sand). Dr. White stated that "oil well borings between Titusville and Lake Erie enable me to identify the famous 'Third Sand' of the oil region with the outcrop of a remarkable set of sand rocks capping the Great Divide overlooking Lake Erie. * * *

"I have traced this deposit across Erie county from the Ohio line to the New York State line."[1]

On the "Geological Map of Pennsylvania" prepared by A. D. W. Smith, under the direction of J. P. Lesley, and published in 1893, the Portage flags, Girard shale and Chemung are not separated, but are represented by the color used for No. VIII, of the Pennsylvania Survey, which includes all of the New York formations from the Corniferous (Onondaga) limestone to the Chemung formation inclusive. The area mapped as the "Venango Oil Sand Group" by Dr. White appears on the State Geological Map of 1893 as the Catskill (No. IX of the Pennsylvania Survey).

The Warren Folio[2] by Charles Butts, has recently appeared covering the northeastern part of Warren County, which is the next one east of Crawford and Erie counties in Pennsylvania, and south of Chautauqua and Cattaraugus counties in New York. In this quadrangle the Portage formation is unexposed, but from well records its thickness is given as 1,330 feet, in the upper part of which is the well known Bradford oil sand. The Chemung formation is next in ascending order composed of shales and sandstones, with a thickness of 1,120 feet. The lower part of the formation is unexposed, and contains the Warren group of oil sands. A large part of the upper 450 feet of the formation consists of purplish or chocolate colored rock, which the drillers call "pink rock," and its upper limit is taken for the top of the formation. Fossils are abundant throughout the formation, among which are "such highly characteristic Chemung species as *Spirifer mesacostalis*, *Schuchertella* (*Orthothetes*) *chemungensis*, *Athyris angelica*, *Chonetes scitulus*, *Grammysia communis*, *Mytilaria chemungensis*, a number of species of *Productella*, *Leptodesma*, *Aviculopecten*, and *Pterinopecten*."[3]

It is stated that this characteristic Chemung fauna does not continue above the chocolate rocks, which are succeeded by a different phase of sedimentation. To the northeast, in the Olean, New York, region, it begins with the Wolf Creek conglomerate of the New York State Survey. These rocks are named the Conewango formation because they form the valley walls of Conewango Creek from Warren north to the State line, with a thickness of about 550 feet. Near the middle of the formation is a persistent flat-pebble conglomerate known as the Salamanca from the fine exposures north of Salamanca, New York, which Mr.

[1]Ibid., pp. 104–106.
[2]U. S. Geol. Survey, Geol. Atlas, No. 172, 1910.
[3]Ibid., library ed., p. 3, col. 3.

Butts considers probably "the same as the Venango third oil sand."[1] He also states that "there is a marked change in the fossils at the boundary of the Conewango and Chemung formations. The most characteristic species of the genus *Ptychopteria* which come in at the base of the formation and continue to the top, but are unknown in this region either above or below the Conewango. * * * * Westward, in Ohio, the presence of *Ptychopteria* in the Chagrin ('Erie') shale indicates the equivalence of parts, at least, of the Chagrin ('Erie') and Conewango formations."

The name of the Conewango formation, however, was published two years before the appearance of this folio and in a general way it was correlated with the Catskill formation of eastern New York and Pennsylvania and the upper Erie shale of Ohio. The statement of Mr. Butts concerning its correlation to the eastward was as follows: "The 'Conewango and Catskill' formations are, in part, at least, contemporaneous, though differing much in lithologic and paleontologic character.[2] Referring to its correlation to the westward, Mr. Butts wrote as follows: "The rocks below the Olean in New York and western Pennsylvania which were named the Knapp, Oswayo and Cattaraugus beds by Glenn, and are here called Knapp and Conewango formations, carry an entirely distinct assemblage of fossils from the Waverly rocks of Ohio, and the writer was unable to correlate them with any previously described rocks. Girty's work shows that they are to be correlated with the upper part of the Erie shale of Ohio, which carry some of the highly characteristic fossils of the Conewango rocks, though that fact has not, to the writer's knowledge, been published."[3]

The Conewango formation is succeeded by the Knapp formation of the New York State Survey which in the Warren quadrangle is reported as "composed of three members, a conglomerate 20 to 30 feet thick at the bottom, a bed of shale and thin fine-grained sandstone 10 to 40 feet thick in the middle and a conglomerate 20 to 60 feet thick at the top."[4] Mr. Butts stated that "the Knapp formation throughout the northern part of the Warren quadrangle and eastward throughout the northern part of McKean County has long been known in the Pennsylvania state reports as the 'Sub-Olean conglomerate.' "[5]

Mr. Butts also stated that "it is a mooted question whether the Conewango and Knapp formations * * * should be included in the Devonian or in the Carboniferous system. They have generally been included in the Devonian and they certainly contain Devonian fossils. * * * * However, a marked faunal change takes place at the base of these rocks. Most of the forms occurring so abundantly in the Chemung do not appear in later beds but are succeeded by new forms, some of which have decided Carboniferous affinities. When this

[1]Ibid., p. 4, col. 3.
[2]Top. and Geol. Surv. Pa., 1906-1908, 1908, p. 198.
[3]Ibid., p. 191.
[4]U. S. Geol. Survey, Geol. Atlas, No. 172, p. 5, col. 1.
[5]Ibid., p. 5, col. 2.

fauna was first studied at all carefully, by Clarke and Butts, the opinion was expressed that these rocks might best be regarded as Carboniferous, a view that has since been supported by more thorough study. It seems best to treat them, therefore, under the term Devono-Carboniferous rocks, by which their doubtful position is indicated."[1]

The undoubted Carboniferous is introduced by a fossiliferous sandstone from 2 to 5 feet in thickness, which is correlated with the Berea. Mr. Butts' statement is as follows:

"Nothing that can be identified as the red Bedford shale of Ohio has been seen in the Warren region. In Ohio the Berea sandstone (grit) overlies the Bedford shale and is 5 to 175 feet thick. The Berea sandstone has been traced eastward from Ohio by Girty and found to be the same as the 'Corry' sandstone at Corry, Pa. Identifying it by its abundant and highly characteristic fauna, he was able to follow it still farther east into this [Warren] quadrangle. It has not been seen exposed in place in the quadrangle, but loose pieces of sandstone, crowded with its fossils, have been found at many points in such position as to indicate that their parent bed immediately overlies the upper member of the Knapp formation, whether that be conglomerate or sandstone."[2]

Two years earlier, Mr. Butts had called attention to this correlation when he stated that "in 1904 Geo. H. Girty completed studies in northeastern Ohio and northwestern Pennsylvania which enabled him to identify the Berea sandstone of Ohio with the Corry sandstone of Pennsylvania, and to trace the latter definitely by its very characteristic assemblage of fossils to the Allegheny river at Warren, where it, in places, lies close below the Olean conglomerate, the latter bed in places lying on beds below the Berea on account of the erosional unconformity in the region."[3]

The succeeding green shales, thin, fine-grained green sandstones and flat-pebble conglomerates, varying in thickness from 5 to 200 feet, are "believed to be the stratigraphic equivalent of the Cuyahoga of Ohio as the term was originally applied." The formation is only a few feet in thickness north of the Allegheny River; but increases to more than 200 feet at the south margin of the quadrangle and contains two or three conglomerate layers "from 2 to 10 feet thick and about 60 feet apart vertically. It is likely that each of these beds has passed as 'sub-Olean conglomerate' at some point or other in the region, the uppermost one being at least 200 feet above the Knapp formation, which is also called 'sub-Olean conglomerate' where it outcrops along the river bluffs. The presence of these conglomerates gives to the Cuyahoga formation an aspect quite different from that which it has farther west and southwest."[4]

Correlation of the Ashtabula County Chagrin.—A list of all the fossils which have yet been identified by the writer from the Chagrin

[1]Ibid., p. 4, col. 1.
[2]Ibid., p. 5, col. 2.
[3]Top. and Geol. Surv. Pa., 1906-1908, 1908, p. 191.
[4]U. S. Geol. Survey, Geol. Atlas, No. 172, p. 5, col. 3.

formation of Ashtabula County has been compiled, and with their range is given in the following table:

List of Chagrin fossils from Ashtabula County, Ohio, with Range[1]

	Names of Formations							
	Marcellus	Hamilton	Genesee	Ithaca	Chemung	Chagrin of Ohio only	Waverly series	Mississippian
1. Ambocœlia umbonata (Con.) Hall var. gregaria Hall					x			
2. Athyris polita Hall					x			
3. Camarotœchia contracta Hall				x	x		x	
4. Camarotœchia orbicularis Hall					x			
5. Camarotœchia stephani Hall				x	x			
6. Romingerina (Centronella) julia Winch. (?)					x		x	
7. Chonetes scitulus Hall[2]	x	x			x			
8. Chonetes setiger Hall	x	x	x	x	x		x	
9. Chonetes minutus n. sp.						x		
10. Cyrtia alta Hall					x			
11. Dalmanella leonensis Hall					x			
12. Dalmanella tioga (Hall) Wms.					x			
13. Dalmanella tioga (Hall) Wms. var. elmira Wms.					x			
14. Liorhynchus ashtabulense n. sp.						x		
15. Liorhynchus clarkei n. sp.						x		
16. Liorhynchus mesicostale Hall				x	x			
17. Liorhynchus newberryi Hall						x		
18. Liorhynchus ohioense n. sp.						x		
19. Orbiculoidea alleghania (Hall) Schuchert					x			
20. Productella boydi Hall (?)					x			
21. Productella hirsuta Hall					x			
22. Productella lachrymosa (Con.) Hall					x			
23. Productella lachrymosa var. lima Con.					x			
24. Reticularia præmatura (Hall) Schuchert					x			
25. Schizophoria striatula (Schlotheim) Hall and Clarke[3]				x	x			
26. Schuchertella chemungensis (Con.) Girty					x			
27. Spirifer disjunctus Sowb.					x			x
28. Strophalosia muricata (Hall) Beecher					x			
29. Syringothyris texta (Hall) var. chemungensis Cushing						x		
30. Grammysia cf. undata Hall					x			
31. Leptodesma cf. longispinum Hall					x			
32. Lyriopecten cf. magnificus Hall					x			
33. Modiomorpha cf. tioga Hall					x			
34. Pararca sao Hall					x			
35. Pararca cf. venusta Hall					x			
36. Pterinopecten neptunis Hall (?)					x			
37. Spathella cf. typica Hall				x	x			
38. Sphenotus contractus Hall					x			
39. (?) Cyclonema cf. obsolescens Hall					x			
40. Euomphalus (Straparollus) hecale Hall				x	x			

[1]The range of the Brachiopods is taken mainly from Professor Schuchert's Synopsis of American Fossil Brachiopoda and that of the other species from the volumes of the Palæontology of New York.

[2]Professor Herrick reported this species in the Cuyahoga formation of central Ohio; see Bull. Sci. Lab. Denison Univ., Vol. III, 1888, p. 36, pl. 1, fig. 4.

[3]Professor Schuchert gives the the range of this species as "Middle and Upper Devonian."

In the above table there are 40 entries, of which 30 species and varieties are identified without queries; but 6 of these are confined to the Chagrin, leaving 24 for consideration in reference to correlation. Of these 24 species and varieties, 16 or nearly $66\frac{2}{3}$ per cent are confined to the Chemung formation. *Spirifer disjunctus* Sowb. is not included in the above 16, since it is reported in the Mississippian of southwestern New York, although it has generally been considered one of the most characteristic Upper Devonian species of both America and Europe. Four other species are reported only in the Ithaca and Chemung formations, making 20 in all confined to the Upper Devonian, which is $83\frac{1}{3}$ per cent of the number with a distribution outside of Ohio. If the forms identified with a ? (question mark), and those compared with a species are included, then there is a total of 40 entries, of which 6 are confined to the Chagrin, leaving 34 for consideration. Eight of the species with which Ohio forms are doubtfully identified or compared are confined to the Chemung formation, which makes 24 or $70\frac{1}{2}$ per cent of the 34 entries. Furthermore, with the exception of the forms limited to the Ohio Chagrin, every one of the species is found in the Chemung formation of either New York or Pennsylvania; this is true of those occurring in other formations as well as those confined to the Chemung. It is to be noted, therefore, that 34 forms of the entire list of 40 or 85 per cent of the total Chagrin fauna of Ashtabula County is found in the Chemung formation of New York and Pennsylvania. An inspection of the above table and the facts deduced from it appears to the writer to show that the fossiliferous portion of the Chagrin formation of Ashtabula County in northeastern Ohio is the western continuation of the Chemung formation of New York.

CHAPTER V

THE ROCKY RIVER VALLEY

As has already been explained in the Introduction, this bulletin begins with a consideration of the formations found along the Cuyahoga River and its tributaries, which are then followed to the eastward across the northern part of Ohio into Pennsylvania. In this chapter the formations west of the Cuyahoga Valley will be described as exposed along the Rocky River and its branches in western Cuyahoga, eastern Lorain and northern Medina counties.[1]

Rocky River is formed by the union of the East and West Branches of Rocky River in Olmsted Township in the western part of Cuyahoga County, and flows in a general northerly direction, entering Lake Erie in Rockport Township, some 7 miles west of the Cuyahoga River. The West Branch rises in the high ground of the northeastern part of Medina County, while the East Branch rises in the high ground of the southwestern part of Cuyahoga County in Royalton Township. From the outcrops of Berea grit in Middleburg and Olmsted townships to the junction of the East and West Branches their banks, in general, are high with rocky cliffs, and this is also true for the remainder of the distance to Lake Erie.

As may be inferred from the above statement, the name is an appropriate one, and the river with its branches and their tributaries affords many excellent sections of the formations which it crosses. This was early recognized by geologists and the Cuyahoga County report by Dr. Newberry contains the following:

"*Section of Rocks in the Valley of Rocky River, from Berea to Lake Erie.*

		Feet.
1.	Drift clay	6—12
2.	Cuyahoga shale, with *Lingula, Discina,* etc.	10
3.	Berea grit, upper bench shelly, lower massive	60
4.	Red shale with thin calcareous bands containing *Macrodon* and *Lingula*	15
5.	Gray shale, no fossils seen	60
6.	Black bituminous shale with fish scales (Cleveland shale); northern outcrop at second bridge above mouth of Rocky River	50
7.	Gray and green shales, with thin bands of sandstone, no fossils seen (Erie shale)	100
8.	Lake surface."[2]	

[1]Rocky River is the first one west of the Cuyahoga and bears much the same relation to it as does the Chagrin River on the east.

[2]Geol. Surv. Ohio, Vol. I, p. 197.

Then Dr. Newberry went on to say that "the old, clay filled valley of Rocky River is cut into by the new valley, at the second bridge from the Lake, in Rockport. There the east side of the gorge is composed of the Erie and Cleveland shales, the west side of clay."[1]

Rocky River.—Rocky River is formed by the junction of the East and West Branches at Olmsted in the northeastern corner of Olmsted Township. From this locality to Lake Erie at the mouth of the river it is only about 6½ miles in a straight line, but on following the river the distance is increased to about 12 miles on account of the many bends and oxbows in its course For the greater part of this distance it is bordered by steep banks, frequently about a hundred feet in height, which along the northern part of its course rise in general rather abruptly from the stream. Along the southern course of the main river there is more of a flood plain, which occasionally reaches the width of half a mile.

The most northern highway and electric bridge on Rocky River is located one-half mile above its mouth, opposite Clifton Park. The western cliff at this locality is steep, and as leveled by Mr. Flory is 97½ feet high. The greater part of this cliff is in Dr. Newberry's upper division of the Erie shale, which he stated "is carried down to the Lake surface just east of the mouth of Rocky River, and forms the cliffs bordering this stream at its mouth, and for two or three miles above,"[2] with a thickness of nearly 100 feet. Dr. Newberry in his section of the rocks in the valley of Rocky River gave 100 feet of Erie shale, which was described as composed of "gray and green shales with thin bands of sandstone, no fossils seen."[3] The greater part of the cliff is composed of blue, gray and some greenish shales, which are both argillaceous and arenaceous; and alternating with these are layers of thin micaceous sandstones which run up to 6 inches and perhaps more in thickness. Some of these sandstones split into a large number of thin layers, and are often gray or bluish-gray in color. The ironstone calcareous layers characteristic of the lower division were not noticed to any extent in this bank. The shales are the predominating part of it and the sandstone is secondary. Apparently the upper part of the cliff is composed of black shale with the lithologic character of the Cleveland, judging from the large number of small pieces on the talus bank. Also as seen from the bridge there is some 10 feet of darker and apparently harder shale forming the top of the cliff. An assistant—Mr. T. G. Roderick—reached this shale at one point from the top of the bank and found it black; but he reported that there was also gray shale. A man familiar with that locality said that in the sewers and other excavations along the street parallel with, and west of, the river there

[1]Ibid., p. 198.
[2]Ibid., p. 163.
[3]Ibid., p. 197.

is about 10 feet of black shale with blue below it. The upper part of the bank appears to show some such line of division between the shales. As weathered, and seen at a distance, the entire cliff looks mainly like a mass of shale; but on nearer approach the layers of sandstone become noticeable as projecting bands. This is an excellent cliff of the upper part of the Chagrin, from which a general idea of its lithologic character may be obtained; but on account of its steepness, like most of those along the lower course of this river, it is a difficult one for detailed study. No fossils were found.

Dr. Newberry stated in 1873, that from Rocky River "westward the beds lie nearly horizontal until at Avon Point they again rise toward the west, and are succeeded by the lower group, which in turn gives place to the Huron shale."[1] In 1889, Dr. Newberry modified this statement and reported that "in all this region the rocks have a general though gentle dip toward the east, rising westward to the great arch of the Cincinnati axis. From Cleveland to Berea this rise is quite conspicuous, and in the early days of our geological explorations it was supposed to continue toward the west. Later, however, it was found that a broad arch was formed in the vicinity of Berea, and thence westward the Waverly series dipped rapidly down to the valleys of Black River and the Vermilion. This dip misled us, and the thinning of the Erie shale, bringing the Cleveland down near to the Huron, caused these two to be confounded, and led to the supposition that the fish-bearing black shales which form the lake shore in Lorain County were the upper part of the Huron. * * * This matter was, however, cleared up by an excursion made by the writer westward from Cleveland in 1886, and it is now definitely established that all the outcrops of black shale in Cuyahoga and Lorain Counties belong to the Cleveland shale, and that none of the fossil fishes described from northern Ohio should be credited to the Huron."[2]

Some study was given to the outcrops in the cliffs along the lake shore and in the streams entering the lake to the west of Rocky River. Most of the results of this study are reserved for a following bulletin, except that some account will now be given of the outcrops as far west as the Cuyahoga-Lorain county line near Eagle Cliff.

The lake bluff from Rocky River for one-half mile west to Willow Creek is rather high and is composed of the western continuation of the Chagrin formation capped by drift. The banks as seen from on top are bluish in color with the more gradual slope of the Chagrin as contrasted with the steep banks of the Cleveland.

At the mouth of Willow Creek there is a cliff $15\frac{1}{4}$ feet high composed of blue to gray argillaceous and arenaceous shales, alternating with layers of thin, blue, laminated, micaceous sandstone. There are

[1]Ibid., pp. 163, 164.
[2]Mon. U. S. Geol. Survey, Vol. 16, p. 127.

also thin layers of black shale. The shales predominate, although probably the thin sandstones comprise one-fourth of the total thickness. The sandstones are somewhat variable in thickness and weather to a rusty or brownish color.

The lake cliffs to the west of Willow Creek well toward the Automobile Country Club grounds at Dover Bay are composed largely of boulder clay and other drift.

On the lake bluff, about two miles west of Rocky River, and opposite stop No. 12 on the Lake Shore Electric Railway, which is the first one east of Dover Bay, is about 25 feet of mainly bluish-gray shale, part of it arenaceous, and thin layers of similarly colored sandstone from a fraction of an inch up to 2 inches in thickness. Alternating with the olive to bluish shale are very thin layers of black shale, only a fraction of an inch in thickness. The shales are about horizontal in this cliff, which is in the upper part of the Chagrin formation; but very thin layers of black shale with the lithologic character of the Cleveland appear, as will be described more fully in later sections. This cliff is just below the house of Mrs. Lawrence.

Outcrops occur on the first stream east of Dover Bay (stop 13 on the Lake Shore Electric Railroad). A short distance below the New York, Chicago & St. Louis Railroad bridge the western bank of the stream furnished the following section:

Section of Bank of Stream at Dover Bay.

No.		Thickness. Feet.	Total thickness. Feet.
4.	Blue, soft shale	1±	7
3.	Black shale, about 9 inches thick	$\frac{3}{4}$±	6+
2.	Mostly blue, soft, argillaceous shale	$4\frac{1}{3}$±	$5\frac{1}{3}$
1.	Black shale down to about water level, about 1 foot in thickness	1±	1

Just below the railroad bridge is a small asymmetrical, open, anticlinal fold.

Above the railroad track is a reservoir, just below which is a fall in the stream. The lower part of the fall is composed of blue shales with layers of sandstone, some of which are 4 ± inches thick. The upper part of the bank is apparently a blackish shale which weathers to a brownish color; but there is also apparently some soft gray shale. At the upper end of the pond or reservoir the western bank, which is more or less weathered, seems to be all black shale. This locality is only a few rods south of the railroad, a little more than three-fourths of a mile south of the lake shore, and the shale is black with the lithologic appearance of the Cleveland to which it is referred. The black Cleveland shale is fairly well shown on the western bank of this stream

above the North Ridge road, and also at various places in the gutter of this highway between the stream just mentioned and Cahoon Creek $2\frac{1}{2}$ miles farther west.

At Dover Bay the lake cliffs, which are some 50 feet high, are composed of gray shales with layers of rather thin sandstones, although a layer toward the top of the cliff is from 4 to 8 inches thick and has been used in the construction of local piers. On the Automobile Country Club grounds, at the steps near the dancing pavilion, which lead down to the lake shore, is a zone of black, hard shale about 4 feet thick, which is 5 feet or more below the top of the cliff. From the base of this zone of black shale down to the lake level the rocks are apparently all gray to bluish shales and thin sandstones. A considerable part of this lower shale is blue and rather hard. At lake level and higher, are blue to gray argillaceous and arenaceous shales, with thin blue to bluish-gray sandstones, which split up into rather thin layers or laminæ (platy sandstones). Above the zone of black shale the rock is again gray shales and thin sandstones, including the 4- to 8-inch standstone stratum. As the cliff is followed to the west there is more of the blue to gray shale and sandstone above the zone of black shale, since the bank is higher and in places there are at least 10 feet of rocks overlying the black shale zone. The writer would refer these cliffs to the Chagrin formation. These banks are all more or less rounded, no sharp angles as in the black shale cliffs farther westward, which is due to the softer character of much of the Chagrin, so that it creeps or closes up more readily. The Cleveland shale on the other hand is hard, so that the joints do not close up readily and sharp angles are left.

Later the cliff at the steps on the Automobile Country Club grounds was leveled by Mr. Roderick and the following section prepared by the writer:

Section of Lake Cliff at Automobile Country Club Grounds.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
9.	Heavy sandstone in top of bank a little west of steps and from 4 to 8 inches thick	--	6±	42	3
8.	Shale zone with thin sandstones, $2\frac{1}{2}\pm$ feet in thickness	2	6	41	9
7.	Thin, bluish sandstones	--	6	39	3
6.	Zone of gray shale and thin, gray sandstone.	5	--	38	9
5.	Apparently continouus black shale	4	9	33	9
4.	Gray alternating with black shale, about a foot thick	1	--	29	--
3.	Mainly gray shale and thin layers of blue micaceous sandstone. The shale is mostly argillaceous, although some is sandy. There are also thin layers of black shale which in the upper part of the zone are 3 inches or thereabouts in				

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
	thickness, and are much more conspicuous than those in the lower part of the bank where as a rule they are very thin, about $\frac{1}{8}$ of an inch thick	26	9	28	--
2.	Blue, laminated sandstone with two shale zones, one 1 inch and the other $\frac{1}{2}$ inch thick	--	9	1	3
1.	Blue shale with a black band $\frac{1}{4}$ inch thick under water. Lake level	--	6	--	6

This bank shows conclusively that there are thin layers of black shale, but inconspicuous, in these banks of blue clay shale and blue sandstone. These deposits are the westward continuation of those forming the lower part of the banks of Rocky River as exposed at the northern electric and highway bridge. The similar stratigraphic shales on the lake shore farther westward show thicker and more conspicuous banks of black shale. The cliffs of the lake shore from Rocky River westward show the gradual increase in the number and thickness of the bands of black shale in the deposits which are the western continuation of those shown on the lower banks of Rocky River. In other words, they show conclusively the gradual lithologic change in the deposits of the Chagrin formation with the appearance of numerous bands of black shale.

At the mouth of Cahoon Creek, nearly $2\frac{1}{2}$ miles west of Dover Bay, the greater part of the cliff is composed of blue to gray shales and thin sandstones, although there are some rather thin layers of black shale. There are layers of sandstone from 2 to 4 inches thick and on the under side of some of these layers are raised ridges like fillings. This under surface of the layer rests on soft shale. Most of the rocks in this cliff have the lithologic appearance of the Chagrin, to which formation they are referred. Nearly a quarter of a mile farther south, where the Lake Shore Electric Railway crosses Cahoon Creek, the low banks near the stream are composed of blue shales and sandstones, alternating with black shales. On the high banks near the end of the trestle, and nearly as high as the tracks, is an abundance of weathered black shale. Farther south and a little below the road turning to the west are light colored shales and thin sandstones in the lower part of the bank and in the bed of the creek, which apparently belong in the Chagrin formation. The banks in the vicinity of the New York, Chicago and St. Louis Railroad bridge over this creek are composed of black shale without any indication of grayish zones, and apparently belong in the Cleveland. This black shale continues up the creek to the North Ridge road, above and below which are fairly high banks of black Cleveland shale.

A little west of Cahoon Creek, near stop No. 28 on the Lake Shore Electric Railway, is a cliff on the lake shore about 45 feet high. The

upper part of the cliff is composed of drift, below which are olive to bluish shales, with thin, micaceous, bluish-gray sandstones, all apparently with the lithologic character of the Chagrin formation. To the west, along the lake shore, there are no exposures of shale, but sand and clay deposits, until the eastern end of Eagle Cliff is reached.

Eagle Cliff is about $2\frac{1}{4}$ miles northwest of the mouth of Cahoon Creek, and the eastern part of the cliff is from 30 to 35 feet in height, and composed mainly of black, hard shale with the lithologic characters of the Cleveland. At the base of the cliff is a little light colored and soft shale, apparently alternating with black. As stated above, however, the greater part of the cliff is composed of black, slaty shale lithologically similar to the Cleveland, to which formation it is referred. The cliff opposite the residence of Mr. F. W. Sears is 53 feet high, the upper 26 of which is composed of soil and black shale, below which is 27 feet of olive and bluish shale. Below Heintz's house the cliff is about 49 feet high, of which the lower 19 feet is composed of bluish and olive shale, then 28 feet of black shale above, on top of which is perhaps 2 feet of soil. On the adjoining lot, owned by Mr. Seagraves in 1903, a well for natural gas was drilled to the limestone, which was reached at a depth of 900 feet and penetrated to a depth of 10 feet. Not much gas was obtained from the limestone, the principal amount coming from the shale.

Numerous wells have been drilled near the lake shore in this region for natural gas and a condensed record of a number of them was furnished by one of the drillers, Mr. Diedrich, of North Ridgeville, Ohio. One drilled on Hull Point, which is to the west of Eagle Cliff, also reached the Devonian limestone at a depth of 900 feet. Mr. Diedrich stated that the upper part of the well passed through alternating white and brown shale, of which the brown is the harder. Deeper, there was brownish shale for a distance, when the brown again alternated with white shale. The lowest 150 to 175 feet was light gray shale before striking the limestone. The cliff at this point is a brownish to black shale down to within about 5 feet of the base, when dark gray shale continues to water level. A short distance farther east, in a small uplift, thin-bedded, micaceous, bluish sandstones are shown below the dark gray shale. At Beach Park, Mr. Diedrich drilled through 800 feet of shale and reached the top of the limestone at that depth. At Avon Point a well drilled for Mr. Wood reached the top of the limestone at a depth of 825 feet. Finally, wells drilled by Mr. Diedrich in Lorain, which is still farther west and at the mouth of the Black River, reached the top of the limestone at a depth of from 680 to 700 feet.

On Rocky River, a little more than a mile south of Clifton Park and opposite the hamlet of Rockport, is a very prominent oxbow bend, with a high and narrow tongue of land extending well to the west in this

bend, on the highest part of which is located a beautiful residence, 130 feet above the river level.

A mile farther south is the high bridge of the Cleveland, Southwestern and Columbus Railway at Kamms, which is 2½ miles east of south of the bridge of the Lake Shore Electric Railway at Rocky River and Clifton Park. At this locality the eastern bank of the river, which is high and steep, is composed mainly of shale. In 1903, a section of the bank was made, when the shales were shown to better advantage than when visited in 1910.

Section of Rocky River Bank at Kamms.

No.		Thickness. Feet.	Total thickness. Feet.
2.	*Cleveland shale.* All apparently black, bituminous shale; but so weathered and covered with talus on the slope that it is almost impossible to say that there are no gray bands in it. Measuring by tape and counting steps of stairway gave 70 feet in each case for the thickness of this zone	70	115
1.	*Chagrin formation.* In the upper portion are some thin layers of bituminous shale, alternating with olive and blue ones. Below these the bank is composed of blue and olive shales, with thin layers of bluish-gray micaceous sandstone. There are also some calcareous and rusty colored concretionary masses of somewhat lenticular shape	45	45

As measured at this time the floor of the bridge is 123 feet higher than the river, and the engineer in the power house said that it was about 120 feet.

Dr. Newberry in his section of the rocks in the valley of Rocky River gave the thickness of the Cleveland shale as 50 feet, which was described as "black bituminous shale with fish scales" with its "northern outcrop at second bridge above mouth of Rocky River."[1]

Wells for gas have been drilled at various places in this region, and according to Mr. F. A. Colbrunn, one in the vicinity of his house in Kamms reached the top of the Devonian limestone at a depth of 1,095 feet. There was no drive pipe in this well and it was drilled in shale which came very near the surface. Black Cleveland shale outcrops at top of gully, just back of Mr. Colbrunn's house, which is only a few rods from the mouth of the well, and shows that it began in the Cleveland shale. The Colbrunn well is only a short distance from the Cleveland, Southwestern and Columbus Railway over Rocky River at Kamms. The best well for gas in this vicinity obtained it at a depth of 725 feet, while most of them are only drilled to a depth of between 600 and 800 feet and do not reach the limestone.

[1]Geol. Surv. Ohio, Vol. I, p. 197.

Wells were drilled on the W. J. White farm, less than one mile southwest of the Cleveland, Southwestern and Columbus Railway bridge, which are reported as between 1,200 and 1,400 feet deep. They yield gas and a thick oil flows in small quantity from one of them. These wells begin at about the top of the Chagrin formation, since on the bank of the run to the west of the highway and 2 or 3 feet lower than one of the gas wells is the apparent contact of the Chagrin and Cleveland shales with black shale continuing on up the stream. The mouth of this well is some 80 or more feet lower than the Colbrunn well at Kamms, and since that reached the Devonian limestone at a depth of 1,000 feet, it is probable if these wells on the White farm are between 1,200 and 1,400 feet in depth that they stop in the Monroe formation. The horizon of the oil may be the Sylvania sandstone, since in well No. 4 of the United Salt Company in Cleveland, it is reached at a depth of 390 feet below the top of the Devonian limestone and these wells have apparently been drilled between 300 and 500 feet deeper than the top of this limestone. It was reported that the deepest ones entered salt water and then the drilling stopped.

Five-eighths of a mile farther up the river on the Henry Mastick farm, near the Mastick bridge, where the highway crosses the river for Puritas Springs, a well was drilled in 1885, which had been used for fuel and light in the farm house until at least the summer of 1904. It was reported, however, at that time that the pressure was not sufficient to furnish enough heat during the winter and wood was used to some extent. The gas in this well was obtained at a depth of 527 feet and came from the Ohio shale.

In Rocky River at the Mastick bridge are thin bluish sandstones and blue arenaceous shale, some 2 feet of which are shown, that are in the Chagrin formation. Black Cleveland shale was found in a small gully on the hill to the west of the river and 50 feet higher; but it is thought that this outcrop is higher than the base of the black shale. In the road gutter to the west of the river, black shale is first shown at an elevation 5 feet higher than that of the outcrop in the gully, and continues up the hill for 25 feet, so that 30 feet of the Cleveland shale is shown on this slope.

A small gully on the hill on the eastern side of the river, and above the lane to the east of the E. A. Mastick farm, shows a thin blue sandstone some 30 feet higher than the river level at the Mastick bridge. Below is another and thicker sandstone, while between them are rather bluish to blackish soft argillaceous shales. There is not a very sharp difference in the color of the shales at this locality; but the highest thin, blue sandstone was considered the top of the Chagrin formation, above which is 40 feet of black Cleveland shale. This locality is on the steep slope of the hill to the northwest of Puritas Springs and at a lower level.

On the bank of the river at water level, nearly a mile above the

Mastick bridge, and about opposite a lane that leaves the north and south highway and runs westerly toward the river, is black, massive shale with the lithologic characters of the Cleveland. Higher, however, on the bank, is an occasional bluish to greenish colored layer, with the lithologic appearance of the Chagrin. This blending of the characters of the Cleveland and Chagrin shales along Rocky River is due to the upper portion of the Chagrin formation being partly replaced by shales with the lithologic characters of the Cleveland, or in other words, to the earlier appearance of shales with the lithologic characters of the Cleveland. At this locality, however, it appears better to refer all of this shale to the Cleveland. On the steep bank, 80 feet higher than the river level, is an outcrop of bluish shale which may be in the Bedford.

Sections near Olmsted.—At Olmsted, the East Branch and West Branch unite to form Rocky River, and at this locality are magnificent banks of black Cleveland shale. The point at the junction of the two branches just south of the highway bridge is a fine one, as well as the one on the western side of Rocky River just below and north of the highway bridge. The one last mentioned is an isolated hill, and a short distance to the northeast, also on the western side of Rocky River, is a similar, although smaller hill, which is separated by a valley from the former one. It appears that the valley of the West Branch was at one time to the west of both of these isolated hills and the two branches united at the end of the divide, which is now the second hill. Later the two streams cut through the divide and made the valley which now separates the two hills, in the same way that still later they have cut through the ridge at Olmsted and made the present narrow valley where the two branches now unite. A view of the end of the present divide as seen from the highway bridge looking up stream which is known as Cedar Point and said to be 100 feet high, is shown in Plate LXIII, while a view of the point below the bridge looking down stream is shown in Plate LXIV.

The upper third of Cedar Point is very steep and perhaps the shale stands out a little more conspicuously than in its lower two-thirds. Perhaps this same statement applies to the point below the bridge and in each instance it is probably due to the upper shale being a little tougher. In the lower third of Cedar Point and perhaps higher are somewhat concretionary lenses of thicker rock which are perhaps sandstone or cone-in-cone layers or even marcasite concretions. As seen from the river bed it appears very difficult to separate this shale bank into two formations. There are, to be sure, thin layers of blue shale in the lower part of the bank; but the black predominates to such a decided extent that the writer has not attempted to separate these shales and has referred all of them to the Cleveland.

A section on the east bank of the East Branch Rocky River a few rods above its junction with the West Branch shows the presence of

Cleveland shale at end of divide (Cedar Point) above junction of East Branch and West Branch of Rocky River at Olmsted.

thin layers of blue shale and sandstone; but also that the black shale is the predominating rock. The section of this bank is as follows:

Section on East Branch Rocky River above Junction of East and West Branches.

No.		Thickness.		Total thickness.	
		Ft.	In.	Ft.	In.
8.	Black shale at top of bank which is hard and slaty like the Cleveland	4	8	7	$9\frac{5}{8}$
7.	Blue, argillaceous shale	--	$\frac{1}{2}$	3	$1\frac{5}{8}$
6.	Blue sandstone	--	$\frac{3}{8}$	3	$1\frac{1}{8}$
5.	Black shale	--	$2\frac{1}{4}$	3	$\frac{3}{4}$
4.	Blue, argillaceous shale	--	$1\frac{1}{2}$	2	$10\frac{1}{2}$
3.	Black shale	1	3	2	9
2.	Bluish shale and thin sandstone	--	2	1	6
1.	Black shale to river level	1	4	1	4

Black Cleveland shale outcrops in the bed of Rocky River at this place and continues nearly, if not quite, to the top of each point. The one below the bridge was measured and Mr. Morse leveled up the point to a height of 93 feet above the river, where there was still enough black shale above him to make its thickness fully 100 feet. The barometer gave a thickness of 90 to 95 feet for the same interval. The contact of the black shale with either the Chagrin or Bedford is not shown.

This locality gives one of the thickest sections of Cleveland shale that has been measured, and its rapid increase from nearly 52 feet on Doan Brook in Cleveland, some 16 miles to the northeast, is due to the black shale deposits at Olmsted having probably replaced the upper layers of the Chagrin, and perhaps the lower ones of the Bedford, as those formations occur in Cleveland.

Professor Cushing has recently proposed the name Olmsted shale for 60 feet of blackish shale on the Rocky River[1] which undoubtedly includes the lower part of Cedar Point and the opposite point at the junction of the two branches of Rocky River. Later Dr. Ulrich states that this name is proposed "by Professor H. P. Cushing for the body of relatively soft, mainly blackish, though partly bluish shale which wedges in at the base of the Cleveland shale in West Cleveland, where it—first the typical Cleveland and then the intercalated bed—rests on and is sharply distinguished from the Chagrin formation. West from Cleveland the Olmsted shale gains with moderate rapidity, attaining a thickness of nearly 100 feet at the western edge of the Berea quadrangle."[2]

The desirability of giving a new name to these shales has been discussed by Dr. Kindle who has written as follows:

[1]Am. Jour. Sci., 4th ser., Vol. XXXIII, June 1912, pp. 582, 583.
[2]Ibid., Vol. XXXIV, August 1912, p. 167.

"The beds thus designated appear to represent beds generally considered transition beds between the Cleveland and Chagrin by the writer and others. The need or desirability of introducing a new name for transition beds at this horizon is a question on which, doubtless, different views will be held. Arguments could be offered for a new member at the top of the Cleveland where locally there is some interbedding. The writer, however, doubts the desirability of introducing a new term for either set of beds. Professor Cushing believes this Olmsted formation to be unconformable with the Chagrin. Evidence will be offered on later pages indicating that sedimentation was not interrupted at this horizon."[1] Again Dr. Kindle states that "Prof. H. P. Cushing has called attention to a considerable mass of interbedded bluish gray and black shale at the base of the Cleveland shale, which he finds west but not east of Cleveland, named by him the Olmsted. If, as the evidence appears to indicate, the Chagrin west of Cleveland grades into and becomes interbedded with the black Cleveland shale, just such beds as Professor Cushing has described would result from and represent this grading."[2]

On the highway to the east of Rocky River and Olmsted, the highest outcrops of black shale are from 80 to 85 feet higher barometrically than the black shale in the river at the bridge.

The highway on the western side of West Branch from Olmsted to Olmsted Falls crosses a run at a distance in a straight line of about one mile to the southwest of the Olmsted bridge over Rocky River. The top of the Cleveland shale is shown on the bank just above the highway bridge, and the base of the Bedford formation is a calcareo-arenaceous layer from 2 to 6 inches thick, in which are rather infrequent specimens of *Orbiculoidea* and *Lingula*. The lower inch or thereabouts of this layer is composed largely of marcasite. The following section was measured on this run:

Section One Mile Southwest of Olmsted.

No.		Thickness. Feet.	Total thickness. Feet.
5.	Drift.		
4.	*Bedford shale.* Most of this interval is composed of chocolate colored shale; but there are some rather thin zones of gray shale	15	80
3.	Bluish to grayish shales, which alternate with blue, compact, very hard and somewhat calcareous sandstones. Shales predominate in the lower 8 feet of this zone; but there are some sandstone layers 3± inches thick. In the upper part of the zone the sandstones are more con-		

[1]Ibid., p. 196, note. The word "not" in the last sentence of the above quotation was inserted in ink in the copy of reprint received from Dr. Kindle.
[2]Ibid., p. 202.

PLATE LXIV.

Cleveland shale in point below junction of East Branch and West Branch of Rocky River at Olmsted. See page 796.

No.		Thickness. Feet.	Total thickness. Feet.
	spicuous, the layers varying from 3 to 4 inches in thickness	$14\frac{1}{2}$	65
2.	Basal arenaceous limestone, from 2 to 6 inches thick, containing specimens of *Orbiculoidea* and *Lingula*, the lower inch mostly marcasite	$\frac{1}{2}\pm$	$50\frac{1}{2}$
1.	*Cleveland shale.* Black shale, finely shown from highway bridge down the run to the West Branch	50	50

This locality was revisited in the summer of 1912 and a more detailed section of the lower Bedford and the subjacent shale down to river level measured. This later section is as follows:

Lower Part of Section One Mile Southwest of Olmsted.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
11.	*Bedford formation.* Bluish, compact sandstone weathering to a brownish color, and 2-4 inches thick. Highest outcrop on bank a few rods above highway viaduct	--	$3\pm$	62	4
10.	Grayish to bluish shale, some of it reddened and containing sandstone concretions	4	5	62	1
9.	Bluish-gray, hard sandstone, weathering to a reddish color and $2\frac{1}{2}$–4 inches thick	--	$3\pm$	57	8
8.	Bluish-gray shale approaching chocolate color in the upper part of zone	2	2	57	5
7.	Blue, hard, very compact layer containing fossils, $1\frac{1}{2}$–2 inches thick	--	2	55	3
6.	Basal layer of Bedford very hard and containing a large percentage of marcasite, $1\frac{1}{4}$–$1\frac{1}{2}$ inches thick	--	1+	55	1
5.	*Cleveland shale.* Top of shale in run a short distance above the highway viaduct. Black, slaty shale with occasional layers that are not so hard, although in general black. These softer ones weather more rapidly so that they are somewhat conspicuous on the banks of the glen. At the base of the zone, as shown below the highway viaduct, are a few inches of hard, black, slaty shale above which is a softer band of black shale. The dip below but near the viaduct is from 3° to 5° S. W.; but this heavy dip does not continue for any considerable distance. Tape measurement	22+	--	55	--
4.	Bluish-black shale which is softer than the layers of black, slaty shale	$1\pm$	--	33	--
3.	Black, slaty shale alternating with softer zones of shale which are nearly black.				

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
	Lithologically like upper part of section. Thickness determined by barometer____	21±	--	32	--
2.	Band of soft, bluish-black shale. Two dikes cross the stream at this locality and one of them when near the south bank branches twice ________________________	1	--	11	--
1.	Black, slaty shale with some softer layers. Near the mouth of the stream is a layer containing numerous marcasite concretions. Level West Branch Rocky River.	10	--	10	--

In the above section the barometer gave the top of the Cleveland as 55 feet higher than the river level at the mouth of the run and the dip makes the actual thickness perhaps somewhat greater. For the same interval in the former section the barometer gave 50 feet. All the distance down the glen, in which the rocks are admirably shown, there are black, hard, slaty shales alternating with zones of softer black shales. In addition are the two zones of soft, bluish-black shale, each one about a foot thick, and the upper one only about 22 feet below the top of the Cleveland shale. It does not appear to the writer that there is any horizon in this glen where a line can be drawn separating this shale into two formations.

At river level a short distance below the mouth of the run is a zone of bluish, argillaceous shale in thin layers, as well as an occasional blue, sandy layer, one of which is one-half inch thick, and these blue layers alternate with thin ones of black shale. In this zone are also somewhat concretionary masses of cone-in-cone. Farther down the river at about the bend and steepest part of the bank this zone of softer bluish shale alternating with black has risen so that it is two feet or more above river level. The zone is about 10 inches thick below which is entirely black, slaty shale like that in the glen. On this bank are not infrequent dikes or joint fillings, sometimes the filling extending horizontally from the joint. There are also lens-shaped sandstone concretions and a rather definite layer of cone-in-cone. This shale bank was estimated as from 60 to 65 feet high, with 20 feet or more of drift and soil above it. The barometer gave 95 feet from river level to the top of the bank near the house of Mr. F. Weiss, which stands a short distance south of the glen. The writer saw no horizon on either this high bank or in the glen where this shale can be separated into two formations.

From the highway bridge down the run to West Branch, and then down this to the Olmsted bridge, black Cleveland shales are finely shown. At Olmsted, as has already been stated, on both the East and West Branches, as well as on Rocky River, are magnificent cliffs of the Cleveland shale. The barometer indicated a very slight fall from the mouth of this run down to the Olmsted bridge, making the

difference in altitude from the contact of the Bedford and Cleveland formations down to river level at the Olmsted bridge, only a little over 50 feet, which agrees fairly well with the topographic map. Another reading gave 65 feet for the same interval. When it is recalled that there is apparently something like 100 feet of mainly black shale in the point of the lower cliff at Olmsted, and that the contact of the Cleveland and Bedford on the run is only a mile to the southwest, it appears that there is a strong dip at this locality in that direction.

On the Maxim farm, three-fourths of a mile south of the run just described, and one and one-fourth miles north of Olmsted Falls, the apparent contact of the Bedford formation and Cleveland shale is again shown. At this locality, which is on the steep bank to the north of the lane, there is a 15-inch layer of sandstone at the apparent base of the Bedford formation, which rests directly on black shale that is considered the top of the Cleveland. At the time of study this bank was in a pasture, and the outcrops were somewhat obscured; but 35 feet of apparently black shale was shown below what was called the top of the Cleveland.

East Branch and Berea.—East Branch for one and one-half miles or farther above its junction with West Branch is bordered on each side by high banks of Cleveland shale. Where the Berea road on the western side of East Branch crosses it, about a mile south of the Olmsted bridge, there are cliffs of black Cleveland shale 65 feet or more in height according to the barometer. The shale at this locality contains specimens of *Sporangites* like those named *Protosalvinia huronensis* by Dawson, and there is a rather heavy dip up stream or to the south. From this crossing up the stream to the Robinson house, a half mile farther south, the western bank is fairly high, and composed of Cleveland shale. The black Cleveland shale is shown in a small run, not far north of the Robinson house, and rather more than a mile below the falls over the Berea grit in this branch. On the eastern side the Cleveland shale is shown in a small gully below the house of M. D. Reublin, where it is massive, with the typical lithologic appearance of this shale. The top of this outcrop, according to the barometer, is 50 feet higher than the level of East Branch, on which is a bank of black shale about 8 feet high. This indicates that at this locality there are some 50 feet of Cleveland shale.

About three-fourths of a mile northwest of the locality just described, and some 2 miles northwest of the center of Berea, a deep well was drilled on the Geo. F. Gray farm. This well is located near Abram Creek, to the west of the highway, and a few rods to the south of it in the creek is black Cleveland shale, which runs up on the bank higher than the mouth of the well. The East Ohio Gas Company reported that the top of the [Devonian] limestone in this well was reached at a depth of 1,075 feet and its bottom at 2,466 feet. A flow of gas amount-

ing to about 500,000 cu. ft. was reached at 1,280 feet; oil and first salt water at 1,400 feet, and the best oil with heavy salt water at 2,230 feet. From the bottom of the limestone at 2,466 feet, down to 2,705 feet, blue and green shale was reported. From 2,705 feet to 3,050 feet, red shale; below which, dark shale extended to its bottom at 3,200 feet. The company reported that the Clinton sand was not found in this well. Mr Geo. F. Gray of Berea, however, stated that the bottom of the well was at a depth of 3,355 feet. Mr. Gray kept a bottle of the different colored drillings from this well, which was examined, although there was no record as to their depth or thickness. There is a light colored band in the bottle which Mr. Gray said is salt, "that was reached at a depth of about 2,000 feet, with a thickness of 45 feet." Below the salt is a light gray band, which he stated is a sand, and below this a very dark band. Toward the bottom of the bottle are two bands of red color which represent the red shales in the lower part of the well and are apparently rather thick. In this well the thickness of the limestones as reported by the company, is 1,391 feet, below which is variously colored shale, the greater part of which is red. In the Newburg well in Cleveland, some 12 miles to the east, Dr. Orton reported the thickness of the rocks from the top of the Devonian limestone to the top of the Niagara limestone, as 1,400 feet; below which the well penetrated an additional 300 feet of Niagara and Clinton limestones, which makes the thickness of the drillers' "Big lime" at least 1,700 feet. If this correlation be correct, unless there is a rapid decrease in the thickness of the limestone formations as followed westward, it would appear that these red shales in the lower part of the Gray well are in the Salina formation of New York. If, on the other hand, the limestone formations decrease rapidly in thickness, so that the base of the Clinton limestone is reached at a depth of 2,466 feet in the Gray well, then the red shales probably represent the Medina and Lewiston shales of New York and the upper part may be of Clinton age. It is not an improbable view that the much greater thickness of salt deposits in Cleveland is accompanied by a greater thickness of other deposits as has been noted where extensive deposits of salt occur in the Salina formation in New York. If this supposition be true, then it is the salt-bearing deposits of Cleveland, which in a general way Dr. Orton correlated with the Salina, that have decidedly thinned by the time the Gray well is reached near the East Branch of Rocky River.

The passage from the Cleveland shale into the Bedford formation is shown in the bed and on the banks of East Branch not far above the bank of black Cleveland shale which is below, and somewhat farther up stream than the house of Mr. M. D. Reublin, and is also one and one-fourth miles or more below the park in Berea. This locality is an interesting one, since it shows the encroachment of the typical Cleveland black shales upon the lower deposits of the Bedford formation.

At low water a gray, impure fossiliferous limestone or calcareous sandstone a foot thick is shown crossing the stream, above which is a zone of black shale about 5 feet in thickness, with the lithologic appearance of the Cleveland. The southerly dip at this locality is heavy for this region, perhaps about 15° in the vicinity of this impure limestone, but decreases rapidly on ascending the stream. A little farther up stream somewhat sandy layers appear above the black shale zone, and above this are bluish shales containing numerous small concretions. This is in turn overlain by another zone of black, fissile shale like the Cleveland, with a thickness of 11⅓ feet, which is capped by another thin impure fossiliferous limestone. These two impure limestones are somewhat concretionary in structure and big masses of impure limestone or sandstone appear at various places in the bed of the river or on the bank. The best place for collecting in the lower impure limestone is in the bed of the stream where it is dipping strongly to the southwest and somewhat above its outcrop on the western bank. Fine specimens of *Parallelodon hamiltoniæ* (Hall) were collected from this outcrop. Above, are grayish shales which gradually pass up into soft chocolate colored ones. The high bank of these chocolate shales is some 200 feet up stream from the zone of blue shale between the two zones of black shale and on the land of Mr. Kindler. The two impure bluish limestones already mentioned are both fossiliferous, containing specimens of *Parallelodon hamiltoniæ* (Hall) and other species. These impure limestones, with a Bedford fauna, apparently indicate that the base of that formation is at least as low as the base of the lower limestone, and not improbably the underlying concretionary sandstone likewise ought to be included in it; but that is so imperfectly shown on the western bank that it is left provisionally in the Cleveland. The two zones of black shale above the lower impure fossiliferous limestone are included in the Bedford formation. A division line, however, based upon the highest conspicuous black shale would be drawn some 24½ feet higher than the lower limestone at the top of the second zone of black shale. The detailed section at this locality, compiled from the outcrops on both banks of the river, is as follows:

Section of Bedford Formation on East Branch, 1¼ Miles below Berea.

No.		Thickness. Ft.	In.	Total thickness. Feet.
14.	*Bedford formation.* The top of the outcrop does not reach the Berea, and this bank is on the Kindler farm. Mainly soft, chocolate colored, argillaceous shale	44	--	86
13.	Some reddish shale; but mainly grayish	6	6	42—
12.	Thin, calcareous layer, an inch or so in thickness	--	1	35⅓

No.		Thickness. Ft.	In.	Total thickness. Feet.
11.	Mainly bluish-gray shale, with thin, arenaceous layers	4	6	$35\frac{1}{4}$
10.	Impure, gray limestone, 2 to 3 inches thick	--	2+	$30\frac{3}{4}$
9.	Mainly grayish shale, some of which is thinly laminated	5	6	$30\frac{7}{12}$
8.	Bluish, impure limestone, containing *Parallelodon hamiltoniæ* (Hall) and other fossils, 2 to 9 inches thick	--	6+	$25\frac{1}{12}$
7.	Black, fissile shale, with the lithologic characters of the Cleveland	11	4	$24\frac{7}{12}$
6.	Blue, arenaceous shale	1	9	$13\frac{1}{4}$
5.	Bluish shale, containing numerous small concretions	3	6	$11\frac{1}{2}$
4.	Blue, rather sandy shale	2	--	8
3.	Black, fissile shale, with the lithologic character of the Cleveland	5±	--	6
2.	Gray, arenaceous limestone or calcareous sandstone, which outcrops on the western bank and in the bed of the river, containing *Parallelodon hamiltoniæ* (Hall) and other species	1±	--	1
1.	*Cleveland black shale.* In its upper part is a concretionary sandstone zone. This blue, thin-bedded, micaceous sandstone is well shown in the bed of the river, on the eastern side, when the water is low. The layers are dipping strongly to the S. 20° W., and dips of 10°, 18°, 21° and 27° were read on layers in different portions of the outcrop. The horizontal distance across the zone is 19 feet 4 inches, and calling the average dip 16°, this gives a thickness of about $5\frac{1}{3}$ feet for the sandstone. In the bed of the river, black shale is clearly shown, both above and below the sandstone; but it has almost disappeared from the bed and bank on the western side. Its top in the bed of the river is about 39 feet in horizontal distance from the end of the arenaceous, fossiliferous limestone, and the dip of the intervening black shale varies from 10° to 19°. Calling the average dip 14°, it makes the top of the sandstone on the western side of the river about 9.4 feet, stratigraphically, below the base of the lower fossiliferous layer. It is evident, however, that this lower sandstone is a concretionary mass of more or less lenticular shape.			

At this locality several small anticlinal folds and faults are shown in the river and on its banks, so that the rocks are considerably disturbed; but it is thought that these were all noted so that there is no repetition in the above section. At one point there is a small overthrust fault with a vertical displacement (throw) of about 3 feet as shown by the broken edges of the second limestone above the base (No. 8).

In the above section the base of the Berea grit is not shown; but if it be correct to consider the lowest limestone (No. 2) as the base of the Bedford, then the formation at this locality has a thickness of at least 86 feet. On the other hand, if the top of the black shale (No. 7) is considered the top of the Cleveland, then the thickness of the Bedford will be $24\frac{1}{2}$ feet less than in the previous estimate, or at least $61\frac{1}{2}$ feet. As already stated, however, it appears to the writer that the Bedford fauna in the lower limestone (No. 2) strongly supports the reference of these $24\frac{1}{2}$ feet of deposits to the Bedford formation.

It is not improbable that some of the upper shale on the point at Olmsted bridge, 2 miles to the northwest, may correspond to some or all of these transitional black shale deposits just described on the East Branch; but on account of the steep face of the cliff it was hardly possible to make a very careful examination of the lithologic character of the shale. The East Branch section is also interesting for comparison with the one on Skinner's Run in Parma Township, 9 miles to the east, where there is $27\frac{3}{8}$ feet of transitional bluish sandstone and black shale from deposits of undoubted Cleveland age to those of undoubted Bedford age. The evidence of the East Branch section apparently favors the reference of the transitional deposits of Skinner's Run to the Bedford formation. In Dr. Newberry's section of the rocks in the valley of Rocky River he gave in ascending order above the Cleveland shale first 60 feet of "gray shale, no fossils seen," followed by 15 feet of "red shale with calcareous bands containing *Macrodon* [*Parallelodon*] and *Lingula*."[1] These two zones, with a combined thickness of 75 feet, represent the Bedford formation in this section.

About three-eighths of a mile farther up East Branch than where the Bedford section was measured, is a cascade in the river formed by two falls, where the stream is cutting through the Berea grit. This cascade is below the railroad viaducts, and the base of the lower fall is 50 feet lower, barometrically, than the top of the Berea grit in quarry No. 6 of the Cleveland Stone Company in Berea. On the eastern bank of the branch, a few rods below the fall and about 5 feet higher than the massive sandstone at its foot, is an outcrop of the chocolate colored Bedford shale, some 8 feet of which is shown. This bank shows an irregular line of contact between the Bedford shale and Berea grit, or in other words, a line of disconformity.

The Berea grit has been quarried many years at Berea, from which

[1]Geol. Surv. Ohio, Vol. 1, p. 197.

locality Newberry named the formation which he described as a drab sandstone, 50 feet thick.[1] A considerable area has been quarried over in and about Berea, but the quarries which were worked the most extensively in the summer of 1911 were the new ones on the western side of the quarry district to the west of East Branch. Beginning at the northern end these quarries are numbered 8, 7 and new 6, the last of which is at the southern end. The foreman of quarry No. 7 of those on the western side gave the thickness of the several divisions in the following section:

Section of Quarry No. 7 at Berea.

No.		Thickness. Feet.	Total thickness. Feet.
6.	*Orangeville shale.* Exposed on the bank above the sandstone	25±	47
5.	*Berea grit.* Upper part shattered and poor grade of stone. The bottom 2 feet of this sheet or course is good rock	5	22
4.	Second sheet of coarse, good rock	8	17
3.	Good rock	2	9
2.	Good rock	5	7
1.	"Flint rock," used for breakwater in Ashtabula harbor. This is bottom of quarry, since there is so much water that it is not practicable to work it and the adjoining ones deeper	2	2

This foreman, who has worked for 31 years in the Berea quarries, reported that now the principal use of the Berea stone from these quarries is for curbing, flagging, grindstones and scythe stones, the latter being made largely during the winter. There is now no considerable demand from these quarries for building or bridge stone. The Amherst quarries, which are located near North Amherst and farther west than Berea, now furnish most of the building stone from this formation.

The quarry known as old No. 6, which was one of the principal ones in 1907, located just west of Elm Street, is now abandoned. The following section was measured in the summer of 1907, and the bank toward the southern end of the quarry furnished that part of the section above the sandstone:

Section of Old Quarry No. 6 at Berea.

No.		Thickness. Feet.	Total thickness. Feet.
8.	Till deposit forming upper part of bank	8½	63
7.	*Orangeville shale.* Bluish-black, compact shale	6	54½
6.	Apparently all compact, black shale, where freshly exposed on the bank above the quarry. No indication of a sandstone was seen in this shale, which was com-		

[1]Geol. Surv. Ohio, Rept. Progress in 1869, (1870), p. 22.

No.		Thickness. Feet.	Total thickness. Feet.
	paratively fresh from recent stripping, and apparently the Aurora sandstone does not occur in the Berea quarries. Certain thin layers contain specimens of *Lingula melie* Hall; but they are not abundant in the shale that was examined	21	$48\frac{1}{2}$
5.	*Berea grit.* Course or sheet No. 4. A layer from 7 to 16 inches thick, and perhaps more, forming the upper part of the Berea, containing a considerable proportion of iron pyrites or marcasite, and weathering to a somewhat shaly structure; hard and not valuable	$5\frac{1}{3}$	$27\frac{1}{2}$ –
4.	Course No. 3, massive quarry stone of light gray color when freshly quarried, similar to the subjacent ones	$6\frac{2}{3}$	$22\frac{1}{12}$
3.	Course No. 2	$7\frac{1}{12}$	$15\frac{5}{12}$
2.	Course No. 1	$6\frac{1}{3}$	$8\frac{1}{3}$
1.	Two feet of sandstone shown at base of quarry	2	2

In the summer of 1911 this quarry was no longer worked and only $9\frac{1}{3}$ feet of the sandstone was shown, as measured at the northern end, the deeper portion being under water.

One of the foremen told the writer that the average thickness of the sandstone worked in these quarries is 20 feet. The upper course is not good; black rock he called it, because it is so stained from the iron pyrites and it is more or less shattered. He reported that a well was drilled for water in one of the quarries near Elm Street, which went down 100 feet in sandstone below the bottom of the quarry. If this statement be correct it indicates that the Berea sandstone in Berea is about 120 feet thick. In 1901 it was reported that in the quarry then called No. 8, they had drilled into the sandstone below its bottom to a depth of 52 feet, which indicated a thickness of at least about 80 feet for the Berea. It is not improbable that the thickness of the Berea is variable in the Berea region as in the quarry districts to the westward. In these, as for example at South Amherst and other quarries, the thickest part of the Berea is found where the sand filled former channels in the subjacent formations. In this old No. 8 quarry there was considerable shaly sandstone at the top of the Berea, and a clay pebbly layer near the top contained a few specimens of *Camarotœchia.*

In 1901 the following section of quarry No. 9 was measured, which is located at the eastern end of the quarry district and is not worked at present:

Section of Old Quarry No. 9 at Berea.

No.		Thickness. Feet.	Total thickness. Feet.
10.	Till forming upper part of bank	$10\frac{1}{2}$	$91\frac{1}{2}$
9.	*Orangeville shale.* On northern wall black shale or grayish-black when weathered	$13\frac{1}{4}$	81 +

No.		Thickness. Feet.	Total thickness. Feet.
8.	Black, bituminous shale, some of it with a bluish tint, containing numerous specimens of *Lingula melie* Hall and some of *Orbiculoidea herzeri* Hall and Clarke	11	67⅚
7.	*Berea grit.* Course or sheet No. 7, which is composed of shaly sandstones, the layers generally thin and containing a considerable proportion of iron pyrites or marcasite; not valuable quarry stone	5⅙	56⅚
6.	Course No. 6. This and the lower courses are all massive quarry stone, which is of light gray color when freshly quarried, but on weathered surfaces it is often stained from the weathering of iron pyrites	4	51⅔
5.	Course No. 5	8⅓	47⅔
4.	Course No. 4	$7\frac{7}{12}$	39⅓
3.	Course No. 3	6¼	31¾
2.	Course No. 2	10	25½
1.	Course No. 1, and bottom of quarry	15½	15½

At the time the above section was measured, 56 feet 10 inches of the Berea sandstone was shown, of which the lower six courses, with a total thickness of 51 feet 8 inches, were all composed of massive quarry stone of good quality.

The shale overlying the Berea sandstone in all of the quarries studied at Berea apparently shows no evidence of the Aurora sandstone; consequently the attempt is not made to separate the Sunbury from the Brecksville shale, and in the sections it has been called simply the Orangeville shale.

In Dr. Newberry's section of the rocks in the valley of Rocky River he gave the Berea grit as 60 feet thick at Berea, and stated that the "upper bench is shelly, lower massive." The section further gave 10 feet of "Cuyahoga shale with *Lingula, Discina,* etc.," as overlying the Berea grit at Berea, above which was 6 to 12 feet of "drift clay."[1]

East Branch and Strongsville Township.—To the south of Berea, in the southern part of Middleburg, and northern part of Strongsville townships, East Branch is bordered by rather high banks of Brecksville shale. Such banks are well shown in the vicinity of the Cleveland, Lorain and Wheeling Railroad, nearly two miles south of Berea.

A branch of Baldwin Creek crosses the northeastern corner of Strongsville Township, and on it, to the south of the most northern east and west road in this township, are blackish argillaceous shales. This outcrop is 95 feet barometrically higher than the level of East Branch, one and three-fourths miles to the west on the above mentioned east and west road, and is apparently in the Brecksville shale. A little higher, the shale is more of a bluish color, a little coarser and perhaps a little sandy. There are numerous outcrops, however, of bluish-black

[1]Geol. Surv. Ohio, Vol. I, p. 197.

shale along the run for 10 feet higher than the base of the lowest outcrop noted above. Near the upper part of these outcrops are banks 2 feet high, composed of very soft, blackish shale which agree with typical outcrops of the Brecksville. Loose in the run, where these outcrops occur, are thin sandstones, which lithologically closely resemble the Sharpsville at the base of the Royalton formation. Five feet higher bluish sandstone, the layers from 2 to 4 inches thick, occurs in the bank of the run, which apparently is not far from, even if not, in place. *Spirophyton* occurs on slabs of this sandstone lying in the bed of the run. These sandstones are 110 feet barometrically higher than East Branch at the highway crossing mentioned above, and apparently are from the basal portion of the Royalton formation. This run crosses the first north and south road to the east of these outcrops near the house of Ph. Webster. Mr. Morse found outcrops of this sandstone to the east of this north and south road, and some 35 feet higher than those in the run, which are apparently near the base of the Royalton formation.

In the northwestern part of Royalton Township, $2\frac{1}{2}$ miles east of the outcrops just described, something of a section in the Royalton was found along the upper course of another branch of Baldwin Creek and the highway. This run crosses the highway at the second four corners on the most northern east and west road in the northwestern corner of this township, and the outcrops are to the northeast of these corners and school-house.

Section in Northwestern Part of Royalton.

No.		Thickness. Feet.	Total thickness. Feet.
6.	*Royalton formation.* Thin, rusty colored sandstones, shown in the gutter on the east and west road, which is the first one north of North Royalton, and just west of the Thomas Hurst farm. The junction of this road with the north and south one to North Royalton is at the house of Wayland Edgerton, which is, according to the barometer, 100 feet higher than these sandstones. Lower outcrops along the road gutter, above where the run crosses it, are arenaceous shales, which are very rusty colored from iron staining	20	$120\frac{1}{2}$
5.	More or less covered interval along the run to the north of the highway	10	$100\frac{1}{2}$
4.	In the upper part, thin-bedded sandstones, alternating with bluish shale, and an occasional calcareous or concretionary layer. Lower, loose specimens on the banks of the gully contain numerous segments of crinoids, with an occasional part of a calyx and arms, together with specimens of *Cyrtina, Productus, Schuchertella* and Bryozoa. In the lower part of this zone are blue, argillaceous shales, which alternate with thin, bluish, somewhat calcareous shales and thin layers of sandstone. The calcareous shales are rather fossiliferous, especially at the base of this zone, and		

No.		Thickness. Feet.	Total thickness. Feet.
	contain specimens of *Spirifer*, *Productus*, *Camarotœchia*, *Chonetes* and *Platyceras*	50	90½
3.	Soft, bluish, argillaceous shale	10	40½
2.	Layer of impure, very compact limestone of bluish to purplish color, which weathers on the surface to a rusty color, with a thickness of 6 inches more or less	½±	30½
1.	Soft, bluish, argillaceous shales, immediately below the limestone, and then covered to the school-house and four corners	30	30

The road and gully along which the above section was made are only about three-fourths of a mile south of the most northern east and west road in Royalton Township, on which outcrops were described near the close of the account of the Big Creek sections on p. 354. The base of the above section at the school-house and four corners is 180 feet barometrically higher than the top of the Berea grit in one of the quarries on the bank of Baldwin Creek in Berea.

The highway about one-fourth mile east of Strongsville crosses a run which enters East Branch from the south. The gully part of the run begins at the highway, and in its upper part is a shaly sandstone 15 inches thick. The section described below was measured on following down this run from the highway to East Branch:

Section on Run one-fourth Mile East of Strongsville.

No.		Thickness. Feet.	Total thickness. Feet.
9.	*Royalton formation.* At head of gully at highway level, bluish, shaly sandstones, 15 inches thick, which contain numerous specimens of *Spirophyton*	1¼	124¾
8.	Immediately below the sandstone are bluish, soft, argillaceous shales. The zone, however, is composed mainly of black to bluish, argillaceous to slightly arenaceous shale	12	123½
7.	Bluish, arenaceous shales	3	111½
6.	A bluish sandstone stratum, 8 to 9 inches thick, and full of *Spirophyton* markings	¾	108½
5.	Immediately beneath the sandstone zone, 8 feet of mainly black to bluish-black, soft, argillaceous shale is shown; but there is some that is arenaceous	11	107¾
4.	A layer of shaly, blue sandstone, 2 to 3 inches thick	¼	96¾
3.	Blackish, soft, argillaceous shale	6⅓	96½+
2.	Bluish, shaly sandstone, 3 to 4 inches thick, weathering to a rusty color	¼+	90¼
1.	*Brecksville shale.* From the above thin sandstone zone, soft, black, argillaceous shale extends down the run to the East Branch. According to the barometer, from 90 to 95 feet of this shale is shown, in which are several small folds	90+	90

In the above section, it is perfectly clear that the lower 90 feet or more of black shale all belongs in the Brecksville. As the formations are followed to the southwest from the Cleveland region, the Sharpsville sandstones are largely replaced by shale, so that it is more difficult to decide where the line between the Orangeville and Royalton formations shall be drawn. For example, in the above section, the writer is not positive whether the lowest sandstone, No. 2, should be considered the base of the Royalton formation or the lowest *Spirophyton* sandstone, No. 6, which is 18 feet higher. These *Spirophyton* sandstones were readily recognized in various sections from this region on to the southwest toward Medina, but the lowest thin blue sandstone is thought to represent, stratigraphically, more nearly the base of the Royalton formation in the Cuyahoga Valley sections, and consequently that horizon has been called the base of the Royalton formation in this and other sections up East Branch and West Branch.

On Chippewa Creek, some 10 miles to the east, the lowest *Spirophyton* sandstone is 10 feet above the base of the 5-foot zone of compact blue sandstone, which was considered the basal zone of the Royalton formation. Apparently, this lower sandstone zone of Chippewa Creek has been mainly replaced by shale in this section, so that to the southwestward the lowest *Spirophyton* sandstone becomes the most conspicuous line of division between the Orangeville and Royalton formations. The top of the *Spirophyton* sandstone by the highway is, according to the barometer, 155 feet higher than the top of the Berea grit in one of the Berea quarries. The base of the lowest sandstone in the above section is 34¾ feet lower, which, ignoring the dip between this locality and the Berea quarry, some 4 miles to the northwest, leaves about 120 feet for the thickness of the Orangeville formation. This is in close agreement with its thickness on Chippewa Creek, where it is 115 feet.

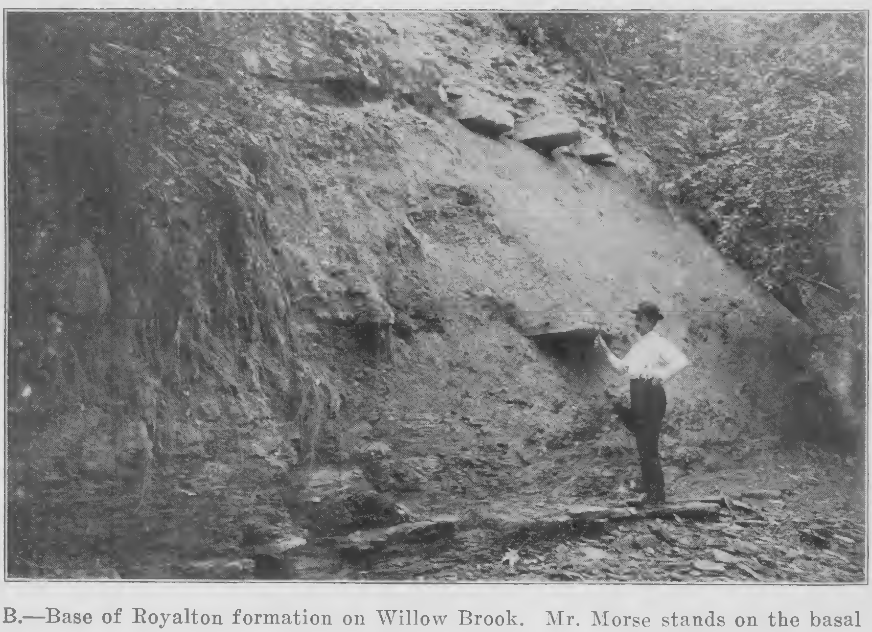
Two miles east of Strongsville, Willow Brook enters East Branch from the south near Roy's Mill, along which, for a distance of about 2 miles, outcrops of the Brecksville shale and Royalton occur frequently. This section was continued over a covered interval of some 60 feet to the Sharon conglomerate on Strong's or Stone Hill in the southern part of Strongsville Township, and northern part of Brunswick Township.

Section from Top of Strong's Hill down Willow Brook to East Branch.

No.		Thickness. Feet.	Total thickness. Feet.
25.	*Sharon conglomerate*. The top of the outcrop is on the north and south road, crossing the hill in front of the John Aylard house, and to the south of the four corners. Mainly light gray sandstone, but in places, as shown along the east and west road cross-		

No.		Thickness. Feet.	Total thickness. Feet.
	ing the northern end of the hill, there are numerous pebbles. The highest outcrops on the east and west road are rather conspicuously glaciated. The lowest 21 feet of this zone is shown in the quarry on the Wm. Whiteman farm, which is mainly a massive, coarse-grained, very light gray sandstone. The upper part of the quarry wall shows some cross-bedding, although it is not very conspicuous	75	410
24.	Covered interval below quarry, at the base of which is a ledge of Sharon conglomerate. Under this ledge is springy ground, indicating that it is near the base of the coarse-grained and porous Sharon sandstone and conglomerate	20	335
23.	Covered interval from lowest ledge on Strong's Hill down to highest outcrops on Willow Brook. Probably nearly, if not all of this interval, belongs in the Royalton formation	60	315
22.	*Royalton formation.* Highest outcrops mainly thin, shaly, blue sandstones, below which are blue shales, containing thin sandstone layers and calcareous, concretionary ones	15	255
21.	Mainly bluish, somewhat arenaceous shales, with numerous thin sandstone layers and calcareous, concretionary ones	10	240
20.	Bluish shales, alternating with thin, blue sandstones. The base of this zone is by the highway bridge abutment, at the school-house of District No. 3, and just east of the house of Mr. A. L. Sanderson. About 3 feet above the base of the outcrop in the road gutter below the Sanderson house, the somewhat coarse, bluish-gray shales begin to be rather fossiliferous and continue so for a couple of feet. The most abundant forms are Brachiopoda and Bryozoa, which in less abundance were noted for 3 or 4 feet above the 2-foot zone. The fossils begin about 2 feet higher than the base of this zone. The lower shales are rather arenaceous, and contain calcareous nodules of blue color, which weather to a rusty brown	25	230
19.	Mainly bluish, fine shales, with numerous calcareous concretions, some of which are fossilifereous	10	205
18.	Blue, shaly sandstone zone, about 1 foot thick	1±	195
17.	Bluish shales, with rather numerous layers of thin sandstones	19	194
16.	Bluish-gray, shaly sandstone, which is slightly calcareous, and contains some poorly preserved fossils	½±	175
15.	Bluish-black shales, with more numerous thin sandstone and concretionary layers than in zone No. 13.	25	174½
14.	Bluish sandstone zone, 4 to 5 inches thick	½—	149½
13.	Bluish-black shales, with thin sandstone and concretionary layers, which are calcareous	20	149

A—Chagrin shale on Conneaut Creek, about six miles southwest of Conneaut.
See page 770.



B.—Base of Royalton formation on Willow Brook. Mr. Morse stands on the basal sandstone, marks the second one, and still higher is the *Spirophyton* sandstone.
See page 813.

No.		Thickness. Feet.	Total thickness. Feet.
12.	Blue and compact sandstone layer	$\frac{1}{2}\pm$	129 –
11.	Bluish-black, soft shales, with an occasional thin, blue sandstone and calcareous, concretionary layers, which weather to a rusty brown color	20	128$\frac{1}{2}$
10.	*Spirophyton* sandstone, 12–15 inches thick, making a small fall in the brook. According to the barometer, this stratum is 20 feet lower than the one about $1\frac{1}{2}$ miles to the northwest, on the highway one-fourth mile east of Strongsville. It appears probable that it is the same stratum at both localities	1 +	108$\frac{1}{3}$
9.	Bluish-black shale, which is somewhat gritty	10$\frac{1}{3}$	107$\frac{1}{3}$
8.	Shaly, bluish sandstone to arenaceous shale, with *Spirophyton*, which is 2 feet 11 inches in thickness	3 –	97
7.	Bluish sandstone zone, with trails on under surface	$\frac{2}{3}$	94 –
6.	Mainly blackish, somewhat gritty shale, containing nodular, rusty colored, calcareous concretions	8	93$\frac{1}{4}$
5.	Thin, bluish, shaly sandstone, which weathers to a rusty color, 3 to 4 inches thick	$\frac{1}{4}$ +	85$\frac{1}{4}$
4.	Soft, blackish, argillaceous shale	4$\frac{3}{4}$	85
3.	Basal sandstone, 3 to 4 inches thick	$\frac{1}{4}$	80$\frac{1}{4}$
2.	*Brecksville shale.* Soft, black, argillaceous shale, 50 feet of which is shown	50	80
1.	Covered by glacial and alluvial deposits to level of East Branch	30	30

Plate LXVI, B, shows the lower part of the Royalton formation on Willow Brook. Mr. Morse is standing on the basal sandstone of the Royalton (No. 3 of the section) and marking with the hammer the second thin blue sandstone (No. 5). Higher on the bank is shown the projecting layer of the lower *Spirophyton* sandstone (No. 7), above which are the shaly sandstones to arenaceous shales of No. 8, which also contain *Spirophyton.*

There are small folds shown on Willow Brook, both below and above the highway bridge at the school-house. Two or three of them are rather sharp anticlines, but apparently they extend for only a short distance.

As will be noted, the above section is a long one for northern Ohio and a good one for studying the transition from the Orangeville formation to the Royalton, and all but about the upper 60 feet of this last formation. In this section, as in the one one-fourth mile east of Strongsville, near the base of the Royalton formation, there are two thin sandstone layers containing numerous specimens of *Spirophyton.* In the Willow Brook section they are separated by 13$\frac{1}{4}$ feet of shale, and in the other by 15 feet of shale. In both sections there are two thin bluish sandstones beneath the lowest *Spirophyton* one before reaching the soft

black Brecksville shale. In the section one-fourth mile east of Strongsville the interval between the top of the Brecksville shale and the base of the lowest *Spirophyton* sandstone is 18 feet, and in the Willow Brook section $13\frac{1}{4}$ feet.

Southwestern Part of Royalton Township.—East Branch crosses the southwestern part of Royalton Township and receives numerous tributaries from the high hills on each side of its course, but the older rocks to a large extent along these streams are concealed by alluvial and glacial deposits. A run of considerable size enters East Branch from the east about a mile above Roy's Mill, but the banks are alluvial and clay, and no shale is shown. The lower course of the stream was followed for a mile up to the first east and west road crossing it.

A run in the southwestern corner of Royalton Township, which lies to the northwest of the road from Bennetts Corners to North Royalton, and enters East Branch from the southwest, shows the transition from the Brecksville shale to the Royalton formation. The highest outcrops studied on this run are above the first east and west highway south of East Branch and near the Wm. Meacher farm.

Section on Run in Southwestern Corner of Royalton Township.

No.		Thickness. Feet.	Total thickness. Feet.
10.	*Royalton formation. Spirophyton* sandstone, containing many impressions of this fossil. Outcrops on bank of run; but is not very conspicuously shown and is some 6 inches thick	$\frac{1}{2}$	$68\frac{1}{2}$
9.	Interval partly covered, but showing in part of it black shale	$6\frac{1}{2}$	68
8.	Sandstones, alternating with arenaceous and rather coarse shales	3	$61\frac{1}{2}$
7.	Hard sandstone, which contains immense numbers of stem-like markings, especially on the under surface, which are cylindrical in shape and fairly long. Higher in the stratum is a considerable number of *Spirophyton* impressions. This sandstone contains a high percentage of marcasite, and it makes a small fall in the run a few rods above the highway culvert	$\frac{2}{3}$	$58\frac{1}{2}-$
6.	Shale zone, $7\frac{1}{2}$ feet thick	$7\frac{1}{2}$	$57\frac{3}{4}$
5.	Bluish, fine-grained sandstone, 3 to 4 inches thick and shown on the eastern bank just below the stone highway culvert	$\frac{1}{4}+$	$50\frac{1}{4}$
4.	Black, soft shale	$4\frac{3}{4}$	50
3.	Blue sandstone, 3 to 4 inches thick	$\frac{1}{4}$	$45\frac{1}{4}$
2.	*Brecksville shale.* All black, soft shale, with the exception of a band of arenaceous, blue shale about 2 inches thick, within 10 feet or so of the top of the Brecksville shale	40	45
1.	Alluvial banks to level of East Branch	5	5

In this section, as in the one on Willow Brook and in the other, one-fourth mile east of Strongsville, there are two thin, blue fine-grained sandstones between the top of the Brecksville shale and the base of the lowest *Spirophyton* sandstone. The interval between the top of the Brecksville shale and the base of the lowest *Spirophyton* sandstone in this section is $12\frac{3}{4}$ feet; in the Willow Brook one, $2\frac{1}{8}$ miles to the northwest, $13\frac{1}{4}$ feet, and in the one one-fourth mile east of Strongsville, $3\frac{1}{2}$ miles to the northwest of the section just described in Royalton, 18 feet. In the Royalton section, the interval between the two *Spirophyton* sandstones is $10\frac{1}{4}$ feet; in the Willow Brook section, $13\frac{1}{4}$ feet, and in the one one-fourth mile east of Strongsville, 15 feet.

This section in the southwestern corner of Royalton Township is an important one, since it shows the transition from the Orangeville formation to the Royalton. The section on the steep hill northwest of North Royalton (pp. 451, 452) shows the greater part of the upper and middle portions of this formation, but does not show the lower part and passage down into the Orangeville formation. These two sections show the greater part of the Royalton formation and are both in Royalton Township, from which the formation is named.

On the western bank of East Branch, on the Wm. Meacher farm, and perhaps one-half mile below the mouth of the run which furnished the above section, is the bank of Brecksville shale some 18 feet high, which has been mentioned in that part of this bulletin in which the sections near North Royalton are described. This is the last bank of Brecksville shale that was seen on East Branch as it was followed up stream.

Olmsted Falls on West Branch.—It has already been stated that Rocky River is formed by the junction of the East and West Branches at Olmsted, and sections in the vicinity of that locality have been described (pp. 796–801). Rather more than 2 miles to the south of Olmsted is Olmsted Falls, where the West Branch cuts through the Berea grit and also from the falls on down stream it shows most interesting contacts of the Berea and Bedford, and Bedford and Cleveland formations.

The contact of the Bedford and Cleveland formations is shown on the eastern bank of West Branch, about one-half mile below the lower bridge over West Branch in Olmsted Falls, and not far below the northern end of the street which extends down the western bank of the river from Olmsted Falls. It is also above the house of Mr. John Speer, Jr., on the eastern side of West Branch. At the base of the Bedford, as exposed on this bank, is a 9-inch or thicker sandstone stratum, similar to the one already described in the run on the opposite side of the river, one mile southwest of Olmsted, and about $1\frac{1}{2}$ miles northwest of this locality. This sandstone stratum is slightly calcareous, and on weathering becomes very rusty in color from the iron. The very black Cleveland shale immediately underlies this sandstone, and some 15 feet of it

is shown on the bank down to river level. A few rods farther down stream some 25 feet of the Cleveland black shale is shown on the steep bank at the upper end of the outcrop. This cliff shows that the shales are dipping very strongly up stream in a direction west of south. The basal sandstone of the Bedford, according to Mr. Morse, is shown in the bed of West Branch not many rods above the bank on which the contact described above occurs. Above this sandstone are shown some blue shale and thin sandstones before reaching the chocolate colored shale.

The next bank up stream above the one on which the contact of the Cleveland and Bedford formations occurs, shows chocolate colored Bedford shale. Opposite this bank, on the western side of the river, is another cliff of chocolate shale.

A run entering West Branch from the east a little farther up stream shows a concretionary and contorted zone at the base of the Berea grit, which is only 10 feet, or a little more, higher than the level of West Branch. Only a few rods farther down the stream, on the opposite bank, is a cliff of chocolate colored Bedford shale 22½ feet high, with at least 5 feet of Bedford below it.

Farther up West Branch, on its eastern bank, and only a few rods below the lower bridge at Olmsted Falls, is a striking bluff of the Berea grit and chocolate colored Bedford shale. The lower part of the Berea is contorted and a mass of chocolate colored Bedford is shown between two banks of Berea sandstone filling channels in the Bedford. At the upper end of the outcrop is chocolate colored Bedford shale, and on top of this dark to bluish-gray argillaceous Bedford shale, which is nearly under a mass of Berea grit that has somewhat concentric layers resembling to a certain extent a great concretion. This sandstone is just a little farther down stream, with a vertical height of some 15 feet. On its northern side is a bank of chocolate colored Bedford shale 20–25 feet high, and 12–15 feet wide, the base of which is near river level. To the north of the Bedford shale is another mass of Berea sandstone filling a channel with the lower layers curving upward to some extent as though conforming in shape to the channel in which the sand was deposited. It has been suggested that slumping may have had something to do with the position of these two masses of sandstone, although the writer did not see the evidence to support this view. The same statement may be made concerning the contact of the Berea and Bedford in some of the other stream sections which have been described, although in the writer's judgment it has not affected to any considerable extent the position of these two formations at the contacts which have been described. A view of this bank in which the channel fillings of Berea sandstone are indicated by arrows is shown in Plate LXV. The chocolate colored Bedford shale forms the smooth part of the bank between the two masses of sandstone.

PLATE LXVI.

Channel fillings in Bedford shale on West Branch of Rocky River below Olmsted Falls. A, Upper Berea sandstone filling. B, Bank of red Bedford shale. C, Lower Berea sandstone filling.

Along this part of West Branch, and below, it is evident that there is a heavy dip up stream. It is also obvious that the upper surface of the Bedford is very irregular, on which occurs the concretionary and contorted lower Berea sandstone. This structure is shown again on the eastern bank of the river a short distance above the lower bridge in Olmsted Falls.

The Berea grit occurs on the bank of West Branch and in the bed of the stream under the lower bridge crossing it in Olmsted Falls. It also forms low cliffs on the eastern bank and along the lower course of Plum Creek, which enters West Branch from the west, a short distance above the lower bridge. About opposite, on the eastern side of West Branch, is a bank of chocolate colored Bedford shale, which is 13 feet high and reaches river level. At the top of the shale bank is a zone of very dark gray to bluish argillaceous shale, perhaps 1½ feet in thickness. A little above the bank of chocolate Bedford shale, although it reaches in the stream bed to within 5 feet of it, is a very much contorted sandstone zone, with the typical Berea sandstone shown a little farther up stream. Part of this sandstone stratum is extremely contorted, and thin sandstone layers stand almost on end as it extends into the river. Some of them contain a large amount of iron pyrites or marcasite. The sand grains in this contorted stratum are rather fine, and on weathering, part of the layers are reddened from the iron. The structure of this contorted stratum is perhaps due to concretionary action on a large scale at the base of the Berea formation. Higher on the bank, and a little down stream, are shown layers of massive Berea grit, with its usual texture and structure, while on the lower part of the bank, and still a little farther down the river, is the smooth bank of soft chocolate Bedford shale.

A few rods farther up the river and at a few feet higher elevation, the massive, coarse-grained Berea sandstone is shown in contact with the Bedford shale, and the contorted or concretionary stratum, so conspicuous a little below, is entirely wanting.

Up the river for some distance the Berea forms its bed and banks, but the walls are not very high. It occurs under the viaduct of the Lake Shore and Michigan Southern Railroad, and a few rods above forms the low fall on which the dam has been built. The bedding in the lower part of the Berea at this locality is very irregular, as is clearly shown in the banks, which in places are perhaps 15 feet high. At the upper highway bridge in Olmsted Falls, the surface of some of the layers of the Berea shows ripple-marks. The top of this outcrop near the upper highway bridge is about 40 feet higher according to the barometer than the base of the Berea above the lower bridge over West Branch in Olmsted Falls.

A deep well located on the Garfield and Caine farm on the Dutch Road, about one-half mile west of Olmsted Falls, was drilled by the

East Ohio Gas Company. The barometer gave the mouth of this well as 85 feet higher than the level of West Branch at the mouth of Plum Creek, which is in the Berea sandstone a short distance above the lower bridge crossing West Branch in Olmstead Falls, although a few rods farther up stream on the opposite bank of West Branch the red Bedford shale extends down to the water level. The barometer also gave it as 20 feet higher than the highest outcrop of the Berea sandstone on Plum Creek just below the Dutch Road bridge over it, and one-half mile east of the well.

Farther down Plum Creek, below the railroad tracks, is the upper fall over the Berea sandstone, and the lower one over the same formation is near its mouth.

Section of Garfield and Caine Well.

	Thickness. Feet.	Total depth. Feet.
Drift	10	10
Berea sandstone	80	90
Bedford and Ohio shales	1120	1210
Top of Devonian limestone at a depth of 1210 feet. Bottom of limestones, which probably include the Devonian, Monroe, "Niagara" and Clinton at 2665	1455	2665
Sandstone (probably Clinton) with showing of gas	15	2680
From bottom of sand, blue shale to top of Medina.	60	2740
Bottom of well, according to Company's record, at a depth of 8 feet in the Medina	8	2748[1]

As has already been stated in the discussion of the well on the Geo. F. Gray farm, to the northwest of Berea, it appears that the thickness of the series of Devonian and Silurian limestone formations decreases from Cleveland westward, consequently it is probable that these wells reached to the depth of the Medina formation. In the Gray well, according to the Company's record, the thickness of the series of limestone formations is 1,391 feet, and in the Garfield and Caine well, 1,455 feet. From the top of the Devonian limestone in the former well, down to the top of red shale (Medina ?) is 1,730 feet, while in the latter well, the interval from the top of the limestone down to what the Company reported as Medina, is 1,530 feet.

West Branch and Baker Creek.—A quarry of some extent has been opened in the Berea grit on the eastern side of West Branch at Westview, in the extreme southern part of Olmsted Township. One of the quarry walls, when measured in 1907, was 43 feet high. The weathered surfaces of some of the benches were considerably stained and did not appear to be a high grade of stone for building purposes. The quarry, however, at that time was worked somewhat extensively, and the stone used for construction and grindstones. Mr. Morse reported the clerk as stating that two wells, 500 feet apart, were drilled at quarry No. 3.

[1]The greater part of this record was published by Professor Bownocker in Bull. 12, Geol. Surv. Ohio, 4th ser., p. 65.

One passed through 140 feet and the other 60 feet of Berea sandstone. The mouths of the wells were at approximately the same level so that it was the base of the Berea which varied, indicating a disconformity. Another quarry in the Berea grit is located on the same side of the river in Columbia Township, one mile south of the one at Westview. The wall of this quarry is some 50 feet high, and grindstones were made from a part of the stone.

Nearly $1\frac{1}{2}$ miles west of the quarry just described, are those at Columbia Station in Columbia Township, of which, in 1911, only the Columbia quarry was actively worked. The following section was measured at the western end of the quarry:

Section of Columbia Quarry.

No.		Thickness. Ft.	In.	Total thickness. Feet.
8.	Soil and till, including boulder clay. The barometer gave 25 feet for thickness of this deposit	25±	--	$84\frac{1}{2}$
7.	Top of *Berea grit;* the upper 4± feet of which is thin-bedded to shaly sandstone, and not valuable. Top course or sheet and No. 7 counting from the bottom of the quarry	5	10	$59\frac{1}{2}$
6.	Course No. 6, massive, light gray, rather coarse-grained sandstone, similar in lithologic appearance to the lower courses	3	8	$53\frac{2}{3}$
5.	Course No. 5	10	4	50
4.	Course No. 4	6	2	$39\frac{2}{3}$
3.	Course No. 3	10	--	$33\frac{1}{2}$
2.	Course No. 2	11	--	$23\frac{1}{2}$
1.	Course No. 1	12	6	$12\frac{1}{2}$

The wall of the quarry was measured with the tape line, course by course, and a total thickness of $59\frac{1}{2}$ feet was obtained for the Berea as shown in it. The barometer gave a thickness of 60 feet from the bottom of the quarry to the top of the sandstone, which is in close agreement with the result obtained by using the tape.

The southwest corner of the quarry when visited was under water, and the foreman stated that it had been worked 8 feet deeper than the present water level, when soapstone was struck. This apparently indicates that the Berea grit is at least $67\frac{1}{2}$ feet thick in this quarry, which is near the thickness of the Berea in this region. The principal use of the stone from this quarry is reported to be for buildings and grindstones.

To the northeast of the Columbia quarry is the large one of the Cleveland Stone Company, which was not actively worked in 1911. The foreman of the Columbia quarry stated that it went no deeper than the Columbia quarry, but one of the quarrymen said that it was called 80 feet deep, or 20 feet deeper than the present floor of the Columbia quarry.

Baker Creek enters West Branch from the east, just below Westview, and this stream was followed across the northeastern corner of Columbia Township and the southwestern one of Strongsville. The course of the creek was followed up to the second east and west road south of Vigil, above which its banks are low to its head-waters about the northern end of Strong's Hill in the northern part of Brunswick Township.

Section along Baker Creek.

No.		Thickness. Feet.	Total thickness. Feet.
11.	*Royalton formation.* Bluish-black shales, with an occasional thin sandstone, none of which is more than 6 inches thick. There are also occasional concretionary, calcareous layers, which as weathered, are of rusty color. Highest outcrops a few rods below the second east and west road south of Vigil. There are a good many small rolls in the shales, so that it is not safe to consider all the increased elevation as representing an increase in the thickness of the rocks	50	177
10.	Upper *Spirophyton* sandstone, which is more massive and thicker than in most of the other sections in Cuyahoga County. It is 1 foot 5 inches thick, contains numerous specimens of *Spirophyton* and is excellently shown on the bank of the creek a few rods below the north and south highway and the Electric line, seven-eighths of a mile south of Vigil. The culvert of the electric road rests on this sandstone, and a few rods above it is a sharp anticlinal fold, which has carried the *Spirophyton* sandstone some 6 feet above the creek level. It is about 25 feet across the base of the fold, and its axis is about S. 20° E. This *Spirophyton* sandstone is also shown high on the creek bank one-half mile down stream a short distance below the Cleveland, Lorain and Wheeling Railroad, and near level of the track	$1\frac{1}{2}-$	127
9.	Mainly fine shale, but with some layers that are coarser	$13\frac{1}{3}$	$125\frac{1}{2}$
8.	Thin, shaly sandstones, alternating with arenaceous shales	$2\frac{3}{4}$	$112\frac{1}{6}$
7.	Lower *Spirophyton* sandstone, which is a compact, 7-inch layer, full of stem-like impressions, with some specimens of *Spirophyton.* This stratum is shown on the bank under the Cleveland, Lorain and Wheeling Railroad trestle	$\frac{7}{12}$	$109\frac{5}{12}$
6.	Mainly black, soft, argillaceous shale	$11\frac{5}{6}$	$108\frac{5}{6}$
5.	Thin sandstone stratum, $3\frac{1}{2}$ inches thick, which is also shown on creek bank a little below the Cleveland, Lorain and Wheeling Railroad trestle	$\frac{1}{4}+$	97
4.	Mainly soft, black shale, but with an occasional thin, sandstone layer	$6\frac{1}{2}$	$96\frac{3}{4}$

No.		Thickness. Feet.	Total thickness. Feet.
3.	Blue, shaly sandstone in bed of creek just below Cleveland, Lorain and Wheeling Railroad trestle. Also shown on bank of creek farther down stream, and about opposite where the creek road turns east toward Vigil. At this locality there are banks of soft, black shale below it which are 20 feet high. It is again shown in the gutter on the road toward Vigil, at the same level as on the creek bank. This is the thin sandstone stratum which in this general region has been considered as marking the base of the *Royalton formation*	$\frac{1}{4}$	$90\frac{1}{4}$
2.	*Brecksville shale.* Banks of soft, argillaceous, black shale, frequently from 10 to 15 feet high and reaching 20 feet in the upper outcrops. The lowest outcrops seen are above the second east and west road south of Westview	65	90
1.	Covered interval to highest outcrop of Berea grit in quarry one mile south of Westview. This indicates about 90 feet for the thickness of the Orangeville formation; but the southerly dip, since the top of the formation is reached 3 miles southeast of this quarry, has without much doubt reduced the amount, and the true thickness of the formation is probably greater	25	25

In the above section, like the one one-fourth mile east of Strongsville, the Willow Brook section and the one in the southeastern part of Royalton Township, there are two thin blue sandstones below the lowest *Spirophyton* sandstone before the soft black Brecksville shale is reached. In the Baker Creek section, the lower part of the Royalton formation occurs at a locality about $1\frac{3}{4}$ miles west of the outcrops of the same part of the formation in the section one-fourth mile east of Strongsville. From the base of the lowest *Spirophyton* sandstone down to the Brecksville shale on the Baker Creek section is 18 feet 7 inches, which is certainly in close agreement with the 18 feet for the same interval in the section one-fourth mile east of Strongsville. In this section the *Spirophyton* sandstones are separated by 16 feet 1 inch of shales and in the one east of Strongsville by 15 feet of shales.

Specimens from the upper *Spirophyton* sandstone (No. 10 of the above section) collected in the creek just below the highway and electric railroad bridges were sent to David White, the distinguished paleobotanist of the U. S. Geological Survey [now Chief Geologist], who wrote as follows concerning them, on December 19, 1911:

"After comparing with our material the specimens you sent, I am disposed to regard them as probably belonging to the form described by Hall as *Spirophyton velum.* The fragments are all very incomplete;

yet they appear to compare best with other material in the collections which I provisionally refer to this species."

The banks of West Branch, from the quarry one mile south of Westview, are reported as alluvial or composed of sand and gravel until one-half mile above Hardscrabble (Marysville on the Newberry Geological Map) in the northern part of Liverpool Township in Medina county, where blackish shales outcrop. The banks of most of the streams entering West Branch in the vicinity of Hardscrabble, and somewhat farther north, are also reported as composed of alluvial and drift deposits.

The largest stream, however, in the southeastern part of Columbia Township, which enters West Branch rather more than a mile north of Hardscrabble, has banks of soft, argillaceous Brecksville shale. At a point on it about one-fourth mile north of the Medina-Lorain county line there are banks from 30 to 35 feet high with no indication of layers of sandstone in them. This stream did not furnish continuous outcrops, but the following section was obtained on it:

Section on Stream in Southeastern Part of Columbia Township.

No.		Thickness. Feet.	Total thickness. Feet.
9.	*Royalton formation.* Thin, blue sandstone, 6 inches thick, with marks of trails or tube fillings, which weathers to a rusty color. It is shown on the bank of the stream a few rods below the road running westerly from the north and south county line road. A little farther down the stream, and below the farm-house, in apparently this sandstone, are markings more like stems, and apparently some rather imperfect impressions of *Spirophyton*	½	87½
8.	On the upper bank, underlying the thin, blue sandstone are shown some 6 feet of mostly bluish, arenaceous to argillaceous shales	6	87
7.	Partly covered interval, but mainly bluish shales, with some very thin layers of rusty sandstone. Near base of zone a layer of cone-in-cone and thin rusty sandstones below	9	81
6.	Upper *Spirophyton* sandstone, which is first shown on the northern bank of the run where it is dipping up stream. Upper part 9 inches or more in thickness, containing numerous specimens of *Spirophyton,* below which are several inches of coarse shales, which are underlain by several inches of thin, blocky sandstones. A little farther down the stream and on the opposite bank the entire stratum is shown, which is 1 foot 6 inches thick, composed of blocky sandstone, which splits very irregularly and contains immense numbers of *Spirophyton* impressions. The barometer gave the same elevation for this stratum as for the upper *Spirophyton* sandstone on Baker Creek, below the electric line	1	72

No.		Thickness. Feet.	Total thickness. Feet.
5.	Mainly covered interval, 10 feet thick according to barometer	10	$70\frac{1}{2}$
4.	Lower *Spirophyton* sandstone, exposed in bed of run, 4 inches or more in thickness, containing *Spirophyton* impressions and big plant-like stems or algæ	$\frac{1}{3}$+	$60\frac{1}{2}$+
3.	Bluish, arenaceous shales are exposed 5 feet below the lower *Spirophyton* sandstone, but for some distance above and below the north and south highway, near the house of Richard Putt, the rocks are mostly covered. This interval is 25 feet thick according to the barometer	25±	$60\frac{1}{4}$+
2.	Shaly, blue sandstone to very arenaceous shale on bank of run some 80± rods below the highway and house of Richard Putt, which is 3± inches thick. Below this sandstone, on the same bank, is from 7 to 8 feet of black, soft, argillaceous shale, which is considered the upper part of the Brecksville	$\frac{1}{4}$±	$35\frac{1}{4}$
1.	*Brecksville shale.* Soft, black to bluish-black, argillaceous shale shown down the stream to the lowest outcrops noted. Apparently there are one or two rather thin zones of bluish, somewhat arenaceous shale on one of the banks in the upper part of this member	35	35

On Baker Creek, $2\frac{1}{2}$ miles to the northeast, the interval from the base of the upper *Spirophyton* sandstone down to the top of the Brecksville shale is $35\frac{1}{2}$ feet, and from the lower *Spirophyton* sandstone to the Brecksville shale $18\frac{5}{6}$ feet. In the above section it is 25 feet barometrically lower from the *Spirophyton* stratum to the top of the Brecksville shale.

Black shales are shown where the north and south road crosses both branches of this stream as the road is followed south to the county line.

To the south of Columbia Township, Lorain County, is Liverpool Township, Medina County, and the banks of the streams entering West Branch from the east are to a considerable extent composed of glacial deposits which conceal the older formations. The stream crossing the north and south (State) road about $1\frac{1}{4}$ miles south of Beebetown, however, has outcrops of the Royalton formation along its banks at frequent intervals from a little below the highway down to the Cleveland, Lorain and Wheeling Railroad.

Section on Stream in Northeastern Part of Liverpool Township.

No.		Thickness. Feet.	Total thickness. Feet.
8.	*Royalton formation.* Thin, even-bedded, buff sandstone on bank of creek below the J. T. Mayer house. The		

No.		Thickness. Feet.	Total thickness. Feet.
	sandstone is fine-grained and the layers vary from about ½ to 2 inches in thickness	10	150
7.	Hard, blue, calcareous layer, with sandstone below, which contains specimens of *Spirophyton* and branching tube fillings or stems. The texture of the calcareous layer is something like that of the Meadville limestones. It is 6 inches thick; the *Spirophyton* sandstone 5 inches thick and the two zones separated by 3± inches of shale	$1\frac{1}{6}$	140+
6.	A little lower than the above zone are certain rather calcareous layers, which contain immense numbers of Bryozoa and some Brachiopods, as *Productus*, *Camarotœchia*, etc. These thin, even-bedded, buff to blue sandstones continue down the stream to the lower end of the woods. They contain an occasional ferruginous, somewhat calcareous layer, and weather to a rusty color. Fossils are not infrequent. The sandstones alternate with some layers of shale	24	139
5.	Covered zone	10	115
4.	Bluish, arenaceous shales, with thin layers of sandstone and calcareo-ferruginous, lenticular, concretionary layers. Zone partly covered	15	105
3.	Layer of blue sandstone, with some markings like plant-stems. Below this layer the rocks are partly covered down to the Cleveland, Lorain and Wheeling Railroad bridge, but there are occasional low banks of shale and bluish sandstone, together with some calcareous layers	25	90
2.	Below the railroad bridge, down to the east and west highway, no outcrops of the older formations were seen, and the banks are mostly glacial	65	65
1.	So far as examined, no outcrops of the Waverly rocks were found below the highway bridge, and the owners of the farms along this stream said there was none.		

In the vicinity of Hardscrabble (Marysville), there are fairly high banks of sand and gravel on the West Branch, both below and above the highway crossing the river at this locality. Farther up the river toward Liverpool, black shale is shown along the stream and in the lower part of the banks. On the eastern bank of West Branch, a short distance below the Liverpool bridge, 5 feet or more of black shale is shown. There are also numerous loose blocks of *Spirophyton* sandstone on the bank and above the shale alluvial and sandy deposits.

A short distance above the Liverpool iron bridge is a fairly high rock bank on the eastern side of the river, which was studied by both Mr. Morse and the writer.

Section on West Branch above Liverpool Bridge.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
7.	*Royalton formation.* Bluish to blackish, argillaceous to arenaceous shale and thin sandstones. Zone partly covered	5	6	23¼	
6.	Lower *Spirophyton* sandstone. A stratum of hard, blue sandstone with *Spirophyton* impressions and plant-like stems on the under side	--	7	17¾	
5.	Blackish, argillaceous shale, containing one or two indeterminate, calcareous, sandstone layers	10	--	17⅙	
4.	Blue, fine-grained, calcareous layer, which weathers brown	--	1½	7⅙—	
3.	Bluish-black, arenaceous shales	3	6	7	
2.	Blue sandstone stratum and where it fails the arenaceous material penetrates the shales both above and below. It varies in thickness from 0 to 2 inches	--	2	3½	
1.	Blackish, argillaceous shale, which is slightly arenaceous, to river level	3	4	3⅓	

There is a small run that comes down from the southeast and crosses the east and west highway not very far northeast of the cliff just described. In the banks of this run on the southern side of the highway is soft, black shale, while just below the old cheese factory and above the black shale is a layer of *Spirophyton* sandstone making a small fall in the run. This is the same stratum that was described as zone No. 6 of the section on the river bank. Above the lower sandstone on the run the rocks are mostly covered, but some black shale is shown in place and numerous loose blocks of *Spirophyton* sandstone. Fifteen feet higher than the lower stratum of sandstone is apparently part of the broken down layer of upper *Spirophyton* sandstone. Above this sandstone is some blue clay on the banks of the run and numerous fairly large loose blocks of *Spirophyton* sandstone, while 10 feet higher is a big block of *Spirophyton* sandstone which is probably not in place. Higher than this block the banks of the run as far as followed are composed of clay and sandy drift. These loose blocks of *Spirophyton* sandstone, however, appear to be pretty conclusive evidence that there is another *Spirophyton* sandstone above the one forming the fall in the run, which is the same as the one shown on the bank of the river. This fact, in connection with other stratigraphic evidence, seems to make it reasonably certain that stratum No. 6 of the section is the lower *Spirophyton* sandstone.

In the section on the river bank just above the Liverpool bridge the interval from the lower *Spirophyton* sandstone (No. 6) down to the thin blue sandstone stratum is 13 feet 7½ inches. On Baker Creek the

interval between the lower *Spirophyton* sandstone and the first subjacent blue sandstone is 11 feet 10 inches, while the thickness of the interval from the base of the lower *Spirophyton* sandstone down to the top of the Brecksville shale is 18 feet 10 inches. Consequently it appears that in the Liverpool section the blue sandstone (No. 2) represents the upper one of the two blue sandstones in the lower part of the Royalton formation and that the rocks are probably not exposed deeply enough to show the lower blue sandstone which has been called the basal zone of the Royalton formation.

About three-fourths of a mile up West Branch from the Liverpool cliff the river is spanned by another iron bridge and the rocks are shown on the banks both above and below it. The following section was obtained by Mr. Morse by combining the outcrops below the bridge on both banks of the river:

Section on West Branch, three-fourths of a Mile south of Liverpool Section.

No.		Thickness.		Total thickness.	
		Ft.	In.	Ft.	In.
9.	*Royalton formation.* Bluish to blackish shales, with sandstone partings; from 8 to 10 feet shown	10	--	$44\frac{1}{6}$	
8.	*Spirophyton* sandstone, the upper 4 to 6 inches of zone a massive, hard, blue sandstone, with numerous impressions of *Spirophyton.* The lower part arenaceous shale to shaly sandstone. Total thickness of zone from 20 to 26 inches	2	2	$34\frac{1}{6}$	
7.	Bluish to blackish, argillaceous shale, which is about 15 feet thick on the eastern bank, although on the western one it is apparently about $20\frac{1}{2}$ feet thick	15±	--	32	
6.	Stratum of blue, fine-grained sandstone which shows *Spirophyton* impressions on the upper surface and plant-like stems on its lower one	--	5	17+	
5.	Blackish, argillaceous shales	10	6	$16\frac{2}{3}$	
4.	Blue, fine-grained, calcareous layer	--	$1\frac{1}{2}$	$6\frac{1}{6}-$	
3.	Blackish, argillaceous shale	3	7	6	
2.	Arenaceous shale to sandstone, perhaps 2 inches thick	--	2±	$2\frac{5}{12}$	
1.	Black shale to river level	2	3	$2\frac{1}{4}$	

As already stated, the above section is a combination of the outcrops below the bridge on both banks of the river. The outcrops on the eastern side begin just below the bridge, while those on the western side are farther down the river. On the eastern bank the rocks are shown from the top of the section down to the 5-inch stratum contain-

ing plant-like stems and *Spirophyton* impressions, with an interval of about 15 feet between the two *Spirophyton* strata. On the western bank the same interval is about $20\frac{1}{2}$ feet.

Cossett Run enters West Branch a few rods above the iron bridge which has been mentioned in the section just described. A short distance above its mouth is a fall over a *Spirophyton* sandstone stratum which is the continuation of No. 8 of the previous section. The upper part of the stratum is a rather hard blue sandstone which weathers to a rusty color, and is a mass of *Spirophyton* impressions with a thickness of from 4 to 7 inches. On the under surface of this sandstone are large numbers of raised stem-like markings or perhaps fillings, which when broken show that they are composed of grains of sand like the rest of the sandstone. Beneath the hard sandstone is fairly coarse, arenaceous blue shale, which in places is a sandstone, and weathers to a rusty color. This shale also contains numerous *Spirophyton* impressions and has a thickness of from 20 to 25 inches. Below are soft blackish shales to the level of West Branch.

Farther up Cossett Run and from 8 to 15 feet higher, according to the barometer, than the top of the *Spirophyton* sandstone in the fall is a rapid formed by a *Spirophyton* stratum, the upper part of which is shown on the bank of the stream a short distance farther up. The lower part of the stratum, as shown in the rapid, is a blue hard sandstone, weathering to a rusty color and containing large numbers of *Spirophyton* impressions which are beautifully preserved, and there are also some of the stems or fillings. The top layer of the upper part of the stratum, as shown on the bank a little father up stream than the rapid, is a very hard, blue sandstone which weathers to a very rusty color and contains immense numbers of *Spirophyton* impressions. The lower portion of this bank is a much more shaly, blue sandstone, which is also literally filled with *Spirophyton* impressions. The dip at this locality appears to be down stream to the northwest and the structure of the stratum is much like that of the one in the fall near the mouth of the run. It was thought, however, when in the field that even if the dip is in that direction this stratum is stratigraphically higher than the one in the fall. If this be correct, then it is apparently the third *Spirophyton* sandstone, numbering from the lowest one upwards, although it resembles structurally rather closely the second one on Baker Creek, south of Vigil. It is not easy to measure the thickness of this upper stratum on Cossett Run, but it is probably not more than 3 or 4 feet thick, and possibly less. It is also not evident that there is much dip down stream. A little farther up the run than the *Spirophyton* bank, and on the northern side, is apparently a slight uplift with a strong dip to the south. Blue shales are shown overlying the *Spirophyton* sandstone. The stream was followed for some distance above this sandstone; but the banks are composed of blue clay and alluvial deposits.

About $1\frac{3}{4}$ miles above Cossett Run, and about one-half mile above the Cleveland, Lorain and Wheeling Railroad trestle, is a cliff on the eastern bank of West Branch 15 to 20 feet in height. This bank is composed of blue shale, alternating with layers of thin blue sandstone, all of which clearly belongs in the Royalton formation. Part of the sandstones are more or less nodular, calcareous and contain iron, so that they weather to a dark brown or rusty color. There is a fairly strong dip which is up stream or in general to the south.

The southern bank of West Branch at the iron bridge, about one-fourth mile south of Abbeyville, shows the following section as measured by Mr. Morse, which is all in the Royalton formation:

Section near Abbeyville.

No.		Thickness. Feet.	Total thickness. Feet.
3.	Fine-grained, bluish sandstone, splitting into thin layers which alternate with bluish shale. Each one comprises about one-half of the entire thickness of the zone	9	$19\frac{1}{2}$
2.	Massive, fine-grained, bluish sandstone	$2\frac{2}{3}$	$10\frac{1}{2}$
1.	Bluish, arenaceous shales and sandstones, the shales predominating	$7\frac{5}{6}$	$7\frac{5}{6}$

One-half mile farther up West Branch, and about $3\frac{1}{2}$ miles north of Medina, under the State road bridge, are thin-bedded sandstones, alternating with bluish shales. The barometer indicated that this outcrop is about 5 feet higher than the river level at the bridge near Abbeyville.

A rather calcareous, blue and somewhat fossiliferous layer is exposed in a run on the E. F. Letterley farm, to the east of the State road, and about $1\frac{1}{4}$ miles north of Medina. This horizon is 85 feet higher, according to the barometer, than the one on West Branch under the State road bridge. It resembles closely the fossiliferous horizon under the bridge over the North Branch of Rocky River at Weymouth, 5 miles northeast of Medina. Barometric readings were taken by Mr. Morse at these two localities, one in the morning and the other in the afternoon of the same day, with a difference of only 10 feet.

In the bed of Champion Creek, to the west of Court Street, Medina, commencing near the Northern Ohio station, are outcrops of grayish somewhat micaceous, arenaceous shales to thin sandstones, with a little bluish shale. Only a few feet of rock are exposed and there are no cliffs. Some of the sandy layers contain a considerable number of specimens of *Schizodus medinaensis* Meek, and *Grammysia hannibalensis* (Shumard) Hall (?).

North Branch.—At Bagdad, some $3\frac{1}{2}$ miles northeast of Medina, is a bank on the southern side of the stream some 30 feet high. The lowest

outcrops are just below the highway bridge, the high bank is above it and the total thickness of the exposures at this locality is about 35 feet. The rocks, especially those of the upper part of the bank, are largely bluish to bluish-gray, thin-bedded and laminated sandstones from 2 to 3 inches thick. In the lower outcrops the sandstones, as a rule, are thinner and there is more blue shale; but the sandstone still predominates. One impure layer of limestone, about 6 inches thick, was noted. There are certain rather brownish-gray sandstone layers, apparently slightly calcareous and rather thicker than most of them, which are fossiliferous. These layers are more abundant in the lower part of the bank and the others contain but few fossils. One of the somewhat calcareous layers contains specimens of *Spirophyton* in association with others of *Grammysia*. Some of the thin sandstone layers are ripple-marked. These outcrops belong in the Royalton formation.

The next bank on following up North Branch is on the opposite side of the stream, in which the higher sandstones of the lower bank occur, and are rather fossiliferous. At both localities are large numbers of a rather slender, branching Bryozoan and *Spirophyton*, together with large impressions of a stem-like form. There are also some large, rusty concretions which are calcareous, and ripple-marks in some of the sandstones. Farther up the stream are low banks of thin sandstones capped by high banks of till.

Rather more than 1½ miles above the Bagdad bridge is the lower one at Weymouth over North Branch. Under the bridge is a heavy layer of impure limestone some 14 inches thick, the top of which, according to the barometer is 55 feet higher than the lowest outcrop at the Bagdad bridge. Since 35 feet of rocks are shown at that locality, it indicates that the impure limestone under the Weymouth bridge is nearly 20 feet higher than the top of the cliff above the Bagdad bridge. The following section was measured from the level of North Branch at the Weymouth bridge to the top of the hill on the southern side of the stream and about opposite the Weymouth church:

Section at Weymouth.

No.		Thickness. Feet.	Total thickness. Feet.
9.	*Sharon conglomerate.* Near the top of the hill, to the south of North Branch, is a small opening where the conglomerate has been quarried to a slight extent. Base of outcrop	9⅓	110+
8.	Covered interval. Thickness of this and the subjacent interval determined by the barometer	45	100¾
7.	Top of thin-bedded, rusty sandstones, as shown on highway south of the stream	15	55¾
6.	Shales and thin sandstones, as exposed on the northern bank of the stream near the bridge. Base of zone,		

No.		Thickness. Feet.	Total thickness. Feet.
	according to the barometer, 30 feet higher than the top of the impure limestone under the bridge	10	40¾
5.	Covered interval	21±	30¾
4.	Blue shales and thin-bedded sandstones	3	9¾
3.	Blue, fine-grained sandstone on bank above bridge. It contains nodules of iron ore, so that some of the rock is rather heavy. Specimens of *Productus newberryi* Hall also occur in this stratum	3⅓	6¾
2.	Bluish, arenaceous shales	2¼	3 5/12
1.	Impure limestone, which is somewhat fossiliferous, exposed under the bridge	1⅙	1⅙

Another section was measured on the southern bank of the stream and above the bridge referred to in the previous section, or between the lower and upper Weymouth bridges.

Upper Section at Weymouth.

No.		Thickness. Feet.	Total thickness. Feet.
4.	Blue shales, alternating with sandstones; but the shales predominate	17	57¼
3.	Massive, bluish-gray sandstone	3	40¼
2.	Blue, argillaceous and arenaceous shales, alternating with blue to bluish-gray, thin-bedded sandstones. There are some fossils; but they are not as common as in the lower fossiliferous zone	35	37¼
1.	Massive, blue, fine-grained sandstone stratum. This zone rests directly on No. 4 of the previous section, which is composed of 3 feet of blue shales and thin sandstones	2¼	2¼

The above sections complete the account of the stratigraphic geology of the Rocky River district. The description of the numerous sections which have been studied to the westward in the Black, Vermilion and Huron River basins is deferred for consideration in another bulletin with other sections to the south which will connect the upper Devonian and Mississippian of northern Ohio with the deposits of that age in central Ohio.

CHAPTER VI

CORRELATION

Introduction.—A somewhat complete discussion of the correlation and age of the terranes under consideration is reserved for a later bulletin in which they will be described as they have been followed from Rocky River Valley west and southwest to central Ohio. It is perhaps advisable for the convenience of those particularly interested in this subject to call attention to some of the facts presented in this bulletin. In addition, a brief statement is given regarding the age of the older deposits continuing westward from Rocky River, together with some of the evidence from various sources supporting such correlation.

Cleveland Shale East of Cleveland.—The black, bituminous shale called Cleveland decreases in thickness as it is followed eastward from the Cleveland region and apparently disappears in Trumbull and Ashtabula counties. Read believed that the lithologic characters of the Cleveland were gradually replaced by those of the Chagrin (Erie), and mentioned specifically the ravines in Trumbull Township in the western part of Ashtabula County where the change could be seen.[1] The writer did not find this transition in lithologic character so clearly shown as described by Read; but there is no doubt concerning the decreased thickness of the black shale by the time the western townships of Ashtabula and Trumbull counties are reached and there is some evidence to the westward of the gradual lithologic change. No trace of the Cleveland shale was found in the eastern townships of these two counties or in the adjacent part of Pennsylvania.

On Doan Brook, near the Indian Fort in Cleveland, there is 52 feet of black, bituminous shale which is referred to the Cleveland, only it is to be noted that in the lower part there is an occasional layer of light gray, soft argillaceous shale. On Euclid Creek, which is the first excellent section east of Cleveland, it is more than 58 feet thick. On Sherman Creek, west of Wilson Mill, in the Chagrin Valley, the hard, black, bituminous shale has decreased to 30 feet, below which are soft blue shales and thin sandstones with the lithologic characters of the Chagrin. About 27 feet is referred to the Cleveland in Stebbins Gulch, Chardon Township, in the northwestern part of Geauga County. The contact with the Bedford formation is not so sharply marked since part of the upper 5 feet is bluish-gray shale; but there is a sharp line of contact with the Chagrin, below which no black shale was seen. On the

[1]Geol. Surv. Ohio, Vol. I, p. 486.

Chardon-Concord road, to the south of Painesville, there is 35 feet of Cleveland, as nearly as could be determined from the outcrops in the gutters and highway banks.

On Bates Creek, in the southeastern part of LeRoy Township, Lake County, rather more than 11 feet is referred to the Cleveland shale, the greater part of which is hard, black and bituminous; but near the center is a thin blue sandstone layer and bluish argillaceous and arenaceous shales, alternating with black ones. This section supports the view that the black shale of the Cleveland as followed eastward is gradually replaced by rocks with the lithologic character of the Chagrin and Bedford formations. On Phelps Creek, a short distance farther east, 16 feet was referred to the Cleveland, with an 8-inch blue to blackish sandstone 5 inches below the top, while the remaining 15 feet is black shale. On Trumbull Creek in Trumbull Township in the western part of Ashtabula County, more than 20 feet is referred to the Cleveland, most of which consists of black shale; but there are impure layers not so black and a little sandy. The upper part of the Chagrin formation is well shown in this glen and 50 feet below its top is a fairly abundant Chemung fauna. To the south of the glen just mentioned is Crooked Creek, on which is about 18 feet of black shale referred to the Cleveland, below which are sandstones referred to the Chagrin containing *Spirifer disjunctus* Sowb. In Warner Hollow at Windsor Mills is nearly 18 feet of black shale referred to the Cleveland, immediately below which are sandstones containing specimens of *Spirifer disjunctus* Sowb. and other Chemung fossils. On Mill Creek in the southern part of Windsor Township, which is in the southwestern corner of Ashtabula County, is about 16 feet of black shale called Cleveland, below which are bluish sandstones of the upper Chagrin. The above locality is the last one, as the formations were followed toward Pennsylvania, where the Cleveland shale was found. The shale probably extends to the east of the Grand River Valley; but in this comparatively level and drift-covered region there are few outcrops of the Paleozoic rocks. It was not noted, however, in the various sections studied in the more rugged country east of the Pymatuning Creek on either side of the Ohio-Pennsylvania State line.

Chagrin Formation.—It has been stated very frequently in this bulletin that the upper part of the Chagrin formation from the Cleveland region eastward contains a Chemung fauna. Some of the localities where the largest collections were made are Chippewa Creek on the western side of the Cuyahoga River, and Tinkers and Brandywine creeks on the eastern side of the same river; on Big Creek in the southern part of Lake County; on the highway from Madison to Thompson, and at various places in Trumbull, Cherry Valley, Dorset, Richmond, Pierpont and Monroe townships in Ashtabula County. It has also been shown that in these eastern townships of Ashtabula County and in western Penn-

sylvania, at least as far east as the vicinity of Meadville, after the disappearance of the Cleveland shale, *Spirifer disjunctus* Sowb. and a few other species associated with it in the upper Chagrin continue until near the base of the Berea or Cussewago sandstone. This eastern relationship of the Chagrin, Cleveland, Bedford and Berea formations may perhaps be explained by overlap as is urged by Dr. Ulrich. If this be the explanation, then as the land sunk, the Bedford sediments overlapped the black shales of the Cleveland, extending farther eastward, and finally, the coarse sand deposit of the Berea was laid down nearly if not quite on top of the Chagrin formation. According to another view these sediments would be considered as in part of synchronous age, the different lithologic character due to greater distance from land, varying depth of water and other physical conditions under which they were deposited. The alternation of black shale with blue shales and thin sandstones may be considered as evidence of such conditions.

The Bedford-Berea Disconformity. — Another structural character to be considered is the disconformity between the Bedford and Berea formations noted at so many localities from the southwestern part of Ashtabula County to the vicinity of Cleveland and westward. Some of the localities described most fully in this bulletin are Warner's Hollow below Windsor Mills; Phelps and Bates Creeks in the southeastern part of LeRoy Township; Griswold Hollow and Big Creek north of Chardon; Stebbins Gulch in the western part of Chardon Township; on the Aurora Branch of Chagrin River south of Chagrin Falls; in the railroad cut south of Sagamore Creek; on Chippewa Creek, and on Skinner's Run in Parma Township south of Cleveland. Westward from Cleveland the writer has studied similar examples of disconformity between these two formations, one of which, near South Amherst, has recently been described by Mr. Burroughs.[1] Excellent examples of disconformity between these two formations also occur in central Ohio, which have been shown and described to the writer's classes in geology for the last seven or eight years. The writer presented part of the evidence showing such a disconformity in northern and central Ohio in a paper entitled the "Contact of the Bedford and Berea Formations in Ohio" at the Ohio Academy of Science meeting in Columbus, on December 1, 1911, which was published in a recent number of the Journal of Geology.[2] A former student—Prof. Jesse E. Hyde—quoted the writer in May, 1911, as stating in manuscript that in northern Ohio the Bedford and Berea "are separated by an erosion plane."[3]

Devono-Carboniferous Line. — This disconformity between the Bedford and Berea formations together with the fact that Chemung fossils in northeastern Ohio and northwestern Pennsylvania occur nearly

[1]Jour. Geology, Vol. XIX, Dec., 1911, pp. 655-659.
[2]Ibid., Vol. XX, pp. 585-604.
[3]Ibid., Vol. XIX, p. 257.

to the base of the Berea sandstone is regarded by the writer as evidence in favor of drawing the line of separation between the Devonian and Carboniferous systems at this horizon. There is, however, in the basal layers of the Bedford formation a fauna which has been collected at various localities from Euclid Creek, east of Cleveland, to Chance Creek an eastern tributary of Vermilion River and then in central Ohio, near Columbus. Part of the species of this fauna are Devonian, or at least very closely related to New York Devonian species, as for example, *Schuchertella chemungensis* (Con.) Girty and *Parallelodon hamiltoniæ* (Hall); but on the other hand there are others, as pointed out by Dr. Stauffer, which appear to ally it with Dr. Weller's Glen Park fauna of the Mississippian in the Mississippi basin. A probable southerly continuation of the Ohio Bedford fauna has been described by Dr. Foerste in the east-central part of Kentucky.[1] The writer has not yet reached a positive conclusion concerning the age of this fauna, and on that account at present no change is indicated in Dr. Orton's line of division between the Devonian and Carboniferous systems, although present evidence apparently favors drawing it at the contact of the Bedford and Berea formations.

Dr. Orton's Devono-Carboniferous Line.—In 1880 Dr. Orton stated that the Cleveland shale was not the northern continuation of the Waverly black shale (Sunbury) as Dr. Newberry had thought, and concluded that "it is to be hoped that the great black shale will be left undivided in the Devonian series."[2] Dr. Orton again called attention in 1881 to this erroneous correlation of the Waverly and Cleveland shales[3] and wrote as follows concerning "the lower limit of the Waverly group.

"I submit that this boundary ought to remain undisturbed where it has been fixed by unbroken use in the section [southern] of the state where the name originated, viz., at the base of the Bedford shale. Any other base it is impracticable to establish.

"Take the Cleveland shale, for example. This stratum makes the summit of the great black shale as shown across the entire breadth of Ohio, but its base, no man knows. Its fossils at the best are obscure and rare. Practically we cannot afford to throw away a firm and well maintained stratigraphical base for so uncertain and indefinite a boundary as the base of the Cleveland shale would be."[4] During the ensuing thirty years the line between the top of the Cleveland or Ohio shale and the base of the Bedford formation has been the accepted line of separation between the Devonian and Carboniferous systems for all the publications of the Geological Survey of Ohio.

Cleveland Shale West of Cleveland. — Westward from Cleveland black shale sediments similar to those of the Cleveland in its typical

[1]Ohio Naturalist, Vol. IX, 1909, pp. 515-522, and pl. 27.
[2]Ann. Rept. Sec. State [Ohio] for 1879, 1880, p. 594; also see p. 592.
[3]Proc. Am. Assoc. Adv. Sci., Vol. XXX, 1882, p. 170.
[4]Ibid., p. 174.

region, begin earlier in deposits corresponding to the upper part of the Chagrin, and also at certain localities apparently continue later into the early part of the Bedford formation. The encroachment of the black shale on the upper Chagrin has been described on Skinner's Run south of Cleveland, especially in the cliffs bordering Lake Erie west of Rocky River and along the streams entering the lake, as on Rocky River at Kamms and other places. The apparent continuation of the black shale into the lower part of the Bedford was noted particularly in Skinner's Run near the Broadview Road and on the East Branch of Rocky River below Berea.

Fossils of Cleveland Shale.—As is well known, the fossils in the Cleveland shale which have received the most attention are the fish, a list of twenty-eight species appearing in Dr. Newberry's "Paleozoic Fishes of North America," all of which were described by him.[1] Unfortunately, most of these species are confined to the Cleveland shale, consequently their evidence is not as decisive concerning the question of correlation as it would be if they occurred in other formations. Dr. Newberry's principal paleontologic evidence for the reference of the Cleveland shale to the Waverly was based on the presence of three genera of Elasmobranchs, viz.: *Hoplonchus*, *Orodus* and *Polyrhizodus*, which he believed came from the Cleveland shale at Bedford. He wrote as follows concerning this point: "These three genera are characteristic of the Carboniferous system, and have never been found in the Devonian; but they will hardly be accepted as decisive, being specifically new."[2]

Dr. Kindle has recently stated that other collectors as Branson and Hussakof have not found these genera in the Cleveland shale and his opinion is as follows:

"In view of this kind of testimony from paleontologists thoroughly familiar with the fish fauna of the Cleveland shale, both through extended collecting and study of all the important collections made by others, we seem forced to conclude that the Carboniferous fishes which Newberry records from the Cleveland shale came probably from the Sunbury instead of the Cleveland."[3] It appears fairly certain, however, that Dr. Newberry did collect specimens of *Polyrhizodus modestus* Newb. and *Orodus elegantulus* Newb. and Wor. from the Cleveland shale at Bedford.[4]

Dr. Branson has since found one of the species listed by Dr. Newberry in the Cleveland shale, viz.: *Dinichthys intermedius* Newb., in the Huron shale near Huron.[5]

Dr. Newberry listed three species of Brachiopods as identified

[1]Mon. U. S. Geol. Survey, Vol. XVI, 1889, p. 130.
[2]Ibid., p. 128.
[3]Am. Jour. Sci., 4th series, Vol. XXXIII, p. 133.
[4]See discussion of this point under the consideration of the Cleveland shale at Newburg Falls in this bulletin, pp. 342, 343, and Professor Cushing's article (Am Jour. Sci., 4th ser., Vol. XXXIII, June 1912, pp. 581, 582).
[5]Science, N. S., Vol. XXVIII, July 17, 1908, p. 94; and Univ. Missouri Bull., Science ser., Vol. II, No. 2, October, 1911, p. 25.

by Prof. R. P. Whitefield, from the Cleveland shale of northeastern Ohio. These were *Lingula cuyahoga* Hall, *L. melie* Hall and *Discina* (*Orbiculoidea*) *newberryi* Hall.[1] Professor Schuchert in his "Synopsis of American Fossil Brachiopoda" gives the range and distribution of these species as follows: *Lingula cuyahoga* Hall Waverly of Akron and Cuyahoga Falls, Ohio, and Chemung group, Panama, New York; *L. melie* Hall Waverly of Chagrin Falls, and Berea, Ohio, and *Orbiculoidea newberryi* Hall Waverly of Cuyahoga Falls, Akron, and Farmington, Ohio, and Eureka district, Nevada.[2] The accuracy of identification of at least the last species of this list may be questioned since Hall and Clarke have named the form found in the Sunbury shale, which is between the Cleveland shale and the horizon where the type specimens of *Orbiculoidea newberryi* Hall were found, *O. herzeri*. They stated that "this species has come to us from various quarters labeled 'Discina Newberryi, Hall'. With the latter, however, it does not agree."[3]

The most abundant fossils are Conodonts, some of which from the Cleveland shale at Bedford were illustrated by Dr. Newberry in 1875.[4] Later Dr. Hinde found that three of the Cleveland shale species of Conodonts, viz., *Prionides angulatus* Hinde, *P. erraticus* Hinde and *Polignathus dubius* Hinde occur in the Hamilton formation and Genesee shale of New York.[5] Dr. Kindle writes that "so far as the literature shows conodonts have heretofore been unknown in the Ohio shale below the Cleveland member. During the last field season, however, Mr. P. V. Roundy and myself found that these fossils are quite as abundant in the Huron division of the Ohio as they are in the Cleveland shale. I have found the conodont fauna in all the sections of the Huron shale which I have studied in Ohio."[6] His conclusion is that "the conodonts, so far as their evidence is recorded, indicate a Devonian age for the Cleveland shale."[7]

Huron Shale.—In 1870, Dr. Newberry gave the name Huron shale to "the great mass of black, bituminous shale, designated by the former Geological Board as the 'Black Slate'." He further stated that "its outcrop forms a belt from ten to twenty miles in width, reaching from the Lake shore at the mouth of the Huron River, almost directly south to the mouth of the Scioto."[8] Later Dr. Newberry gave more fully his reasons for the selection of this name, together with his opinion concerning its correlation with the formations of neighboring states. He

[1]Mon. U. S. Geol. Survey, Vol. XVI, p. 128.
[2]Bull. U. S. Geol. Survey, No. 87, 1897, pp. 246, 250, 261.
[3]Pal. N. Y., Vol. VIII, pt. 1, 1892, p. 126, f. n.‡
[4]Geol. Surv. Ohio, Vol. II, pt. 2, pl. 57, and also see p. 41.
[5]Kindle, in Am. Jour. Sci., 4th ser., Vol. XXXIII, Feb. 1912, p. 134.
Hinde, in Quart. Jour. Geol. Soc., London, Vol. 35, 1879, pp. 351-368.
[6]Letter of March 1, 1912.
[7]Am. Jour. Sci., 4th ser., Vol. XXXIII, p. 135.
Geol. Surv. Ohio, Rept. Prog., 1869, 1870, p. 18.

wrote as follows: "As we go westward and recede from the old shore the sheet of land-wash becomes thinner, the sandstones and clay shales of New York disappear, while the bituminous shales are more constant, running together and forming a mass, which in Ohio and further south is a very striking feature in the geology. I have called this in Ohio the the Huron shale, because it forms for a long distance the banks of the Huron River, and as it represents several distinct strata in New York and Pennsylvania, it could not with propriety take the name of either of them. By other geologists it has received various names, and has been regarded as the equivalent of each of several strata, distinct and somewhat widely separated in the east. The first geological corps of Ohio called it simply the black shale; Prof. E. B. Andrews, the Ohio black shale; Prof. Edward Orton, the Ohio shale; Prof. E. T. Cox, State Geologist of Indiana, the New Albany black shale, etc., and it has been regarded as the equivalent of the Marcellus, and sometimes of the Genesee of New York. In fact it is neither, but rather both, and it also includes the western extension of the Portage and Hamilton shales. This is shown by the fact that in different localities it has yielded fossils of all these horizons, viz.: *Clymenia complanata, Rhynchonella limitaris* [*Liorhynchus limitare*], *Styliola* [*Styliolina*] *fissurella, Discina lodensis* [*Orbiculoidea lodiensis*], *Lingula spatulata,* etc."[1] Later in the same monograph Dr. Newberry stated that:

"The *Cleveland shale,* through northern Ohio, is a black carbonaceous mass, twenty to sixty feet in thickness. It there rests upon the argillaceous Erie [Chagrin] shale, which at Cleveland is several hundred feet in thickness, but which thins out toward the west; in Lorain and Huron Counties it is sometimes wanting, letting the Cleveland shale down near to or upon the Huron shale, from which it can scarcely be distinguished by its lithologic characters."[2]

Chagrin in general Synchronous with Huron.—As the outcrops of the Cleveland, Chagrin and Huron shales have been studied from Cleveland, westward to the Huron River, it seemed to the writer that the black shales gradually replaced a large part of the bluish or gray shales and sandstones of the Chagrin formation. It appears in a general way similar to the well known change from the sediments of the Sherburne, Ithaca, Oneonta and Catskill formations of eastern New York to those of the Portage and Chemung formations of the Genesee Valley section. The lithologic characters of these two sets of New York formations are very different, and although for many years a source of difficulty and contention among the New York geologists, it has now been clearly demonstrated that the two sets represent the same general period of time. In other words, it appears to the writer that the shales shown on the Huron River represent in a general way the Chagrin formation of the Cleve-

[1]Mon. U. S. Geol. Survey, Vol. XVI, 1889, pp. 57, 58.
[2]Ibid., p. 123.

land region. Also as the Cleveland and Chagrin formations are followed westward from Cleveland it becomes difficult to draw a sharp line of separation between them and likewise on the Vermilion and Huron rivers to sharply separate the Cleveland and Huron shales.

Sections on Huron River.—A study of the outcrops on the Huron River will readily show that the shale is not all black. Three local sections selected from several that were carefully measured will show the correctness of the above statement. The first one is on the eastern bank of Huron River just above the Milan Street bridge in Monroeville.

Section at Monroeville

No.		Thickness. Feet.	Total thickness. Feet.
4.	Solid, black shale, which separates from the bank in large blocks; 10 to 12 feet is shown. *Calamites* occurs near base of this zone	10+	$17\frac{1}{3}$+
3.	Alternating blue, olive and black shales	$2\frac{1}{2}$	$7\frac{1}{3}$
2.	Black shale with a 7-inch band of olive near the middle of the zone	$2\frac{1}{2}$	$4\frac{5}{6}$
1.	Zone composed of blue and olive shale predominating; but also containing layers of black shale a few inches thick	$2\frac{1}{3}$	$2\frac{1}{3}$
	River level.		

The first bank on the western side of Huron River, below the mouth of Seymore Creek and on the Louis Meyers's farm about four miles north of Monroeville, furnished the following section:

Section of Western Bank of Huron River on Meyers's Farm.

No.		Thickness. Ft.	In.	Total thickness. Ft.	In.
8.	All black shale	18±	--	60	6
7.	Gray and blue or olive shale, alternating with some that is black; but the gray to blue predominates. Some lenticular concretions	32	8	42	6
6.	Black shale containing concretions	1	9	9	10
5.	Three zones each of black and bluish-gray shale	1	5	8	1
4.	Bluish-gray shale with two thin, black bands, a fraction of an inch thick	3	8	6	8
3.	Black shale	2	--	3	--
2.	Bluish-gray shale	1±	--	1	--
1.	River level, showing black shale and tops of large globular concretions.				

A steep cliff forms the western bank of the Huron River at the former hamlet of Enterprise below the P. J. Schaffer bridge. The bank

is difficult to climb but the following section was measured just below the Wm. H. Newton house by Mr. T. G. Roderick:

Section of Western Bank of Huron River at Enterprise.

No.		Thickness. Ft.	Thickness. In.	Total thickness. Ft.	Total thickness. In.
21.	Black, hard, bituminous, fissile shale which projects beyond the lower shales as exposed to the north of the middle of this bank. Thickness estimated as from 5 to 6 feet	5+	--	60±	--
20.	Mainly blue argillaceous shale; but with some layers of black shale from 1 to 3 inches thick. On the high bank on the opposite side of the river, above the Schaffer bridge, disc-shaped concretions occur at about the top of this zone.	32	6	54	9
19.	Black shale	3	4	22	3
18.	Blue shale	--	11½	18	11
17.	Black shale	--	10	17	11½
16.	Blue shale	2	2	17	1½
15.	Black shale	--	1½	14	11½
14.	Blue shale	--	6	14	10
13.	Black shale	--	1	14	4
12.	Blue shale	--	4	14	3
11.	Black, hard, bituminous, slaty, fissile shale	2	3	13	11
10.	Blue shale containing irregular more or less disc-shaped concretions	1	--	11	8
9.	Black shale	--	7	10	8
8.	Blue shale	--	7	10	1
7.	Black shale	--	4	9	6
6.	Blue shale	--	3½	9	2
5.	Black, bituminous, hard, slaty, fissile shale containing some large spherical concretions. There are two small ones at almost the top of this zone	7	10½	8	10½
4.	Blue, rather argillaceous shale	--	8	1	--
3.	Black shale	--	2	--	4
2.	Blue shale a little farther up stream than the concretions	--	2+	--	2
1.	River level with rather irregular concretions in blue shale.				

The Enterprise section is farther down the river than the one on the Meyers's farm, below the mouth of Seymour Creek, and nearly one mile to the northeast. Zone No. 21 of the Enterprise section represents the lower part of zone No. 8 of the one on the Meyers's farm, the continuation of which up stream is shown in zone No. 4 of the Monroeville section. Again zone No. 20 of the Enterprise section with a thickness of 32½ feet corresponds to zone No. 7 of the one on the Meyers's farm which is 32⅔ feet thick. All three of these sections are from outcrops

within the region of the typical Huron shale of Dr. Newberry, since he stated that "This [Huron] is the shale which forms the banks of the Huron river at Monroeville and below."[1]

Dr. Kindle's Huron-Chagrin Correlation.—Dr. Edward M. Kindle, of the Canadian Geological Survey, studied these shales in Ohio during the summer of 1911, and reached a conclusion similar to that stated above. He has written as follows: "I came to the conclusion last summer after examining practically all of the exposures of the Ohio shale along the different branches of the Huron River, that the Chagrin could not be deliminated in that section as a distinct formation. My view is that the Chagrin in the 15 or 20 miles east of the Huron changes so rapidly from a sandy gray shale to a finer-grained darker formation that it becomes impossible to treat or recognize it as a distinct formation in the Huron section, although its epoch of sedimentation is doubtless as fully represented there as in the Cleveland section. It appears to me to be a case somewhat similar to that of the east-west Hamilton section in middle Pennsylvania. The first Hamilton section west of Harrisburg shows nearly 800 feet of coarse sandstones with typical Hamilton shale and fossils above and below, the whole having a thickness of about 1,000 feet. Eighty miles to the westward at Altoona the Hamilton formation is 500 feet thick, composed of dark-gray shales, without a trace of sandstone in it."[2]

Dr. Orton's Huron-Erie Correlation. — These conclusions are essentially in harmony with the results obtained by Dr. Orton and so described by him in 1888, when he wrote as follows: "It comprises all of the elements of the northern section. In other words, the so-called Huron shale of central Ohio is the Cleveland, Erie, Huron shale of northern Ohio. It is not a homogeneous mass of black shale, as it is commonly counted, but beds of blue or greenish-blue shale are frequently interstratified with the prevailing black beds, especially in the middle portion of the series. The top and bottom of the column are generally black shale, and the same thing is true in northern Ohio. These facts show the grounds on which the classification now referred to is based, but the objection to it is that no line of division can be drawn between the Huron and Erie or the Erie and Cleveland shales. The records of many drilled wells in northern Ohio show that alternations of black and blue shale recur not once only, but many times, in the formation. This alternation was recognized by Newberry as far back as 1872. He said at that time that the Huron shale in 'its northerly outcrops is somewhat interstratified with the overlying Erie shale' (Geology of Ohio, Vol. I, p. 153). In other words, there is no line of division between the so-called formations. Since that time the facts bearing on the question have been greatly multiplied, and it is now apparent to all who keep acquainted

[1]Geol. Surv., Ohio, Vol. II, p. 189.
[2]Letter of March 1, 1912.

with them, that the truth of geology demands the abandonment of the proposed three-fold division of the shale series. The Huron and Erie divisions are especially misleading, and therefore objectionable. These two terms, as they are used, cover different phases of the same formation."[1] The writer desires to call particular attention to Dr. Orton's concluding statement that the Huron and Erie (Chagrin) divisions "cover different phases of the same formation," which is essentially the opinion reached by him and also apparently by Dr. Kindle as the result of separate individual investigation in all three instances.

Professor Branson's Description of the Ohio Shale.—Dr. E. B. Branson was professor of geology at Oberlin College for several years, and while there devoted considerable time to the study of the Ohio shale and its fauna. He wrote as follows:

"The Ohio shales in the vicinity of Oberlin, Ohio, are about 610 feet thick and quite uniform in color and texture from top to bottom. Within the area discussed in this paper, which extends from east of Elyria to west of Norwalk, the shales are brown to black, with occasional greenish layers, and in a few places one or two layers of fine-grained sandstones one to six inches in thickness are present * * * *

"Conditions of sedimentation were almost uniform while the Ohio shales were being deposited west of Norwalk, but east of this place the Chagrin enters as a wedge with the thin edge to the west. Its calcareous and arenaceous nature indicates shore conditions to the east."[2] Under the heading of "Conclusions" is the statement that "west of Elyria, Ohio, the Ohio shales do not show distinct three-fold division."[3]

Fossil Fish and Wood of Huron Shale.—The Huron shales are not very fossiliferous, but such fossils as they contain support the stratigraphic evidence in favor of referring them to the Devonian. Perhaps as important as any are the fragments of fish—*Dinichthys hertzeri* Newb. [*herzeri*]—contained in some of the large concretions which occur in this shale. Other concretions contain fragments of fossil wood—*Dadoxylon newberryi* Dn. Specimens of both the *Dinichthys* and *Dadoxylon* were collected by the Rev. Mr. Herzer from these concretions in the lower part of the Ohio shale in the vicinity of Delaware. There has been some question concerning the horizon from which the specimens of *Dadoxylon* described by Dr. Dawson came; although Dr. Newberry had stated that "in examining some of these septaria [apparently near the base of the black shale at Delaware] which had been split, apparently by the frost, Mr. Hertzer discovered that they not unfrequently contained masses of silicified wood (*Dadoxylon Newberryi*, Dawson) or fragments of bones that had served as nuclei around which they had formed."[4]

[1]Geol. Surv. Ohio, Vol. VI, p. 25. Also see ibid., Vol. VII, 1893, p. 22, on which a somewhat condensed form of this same account appears.
[2]Univ. Missouri Bull., Science ser., Vol. II, No. 2, Oct. 1911, pp. 23, 24.
[3]Ibid., p. 28.
[4]Geol. Surv. Ohio, Vol. I, pt. 2, Palæontology, 1873, p. 320.

Dr. Newberry in his monograph of "The Paleozoic Fishes of North America" also stated that "of *Dinichthys Hertzeri* [*herzeri*], from the Huron shale, we have no more new material. The Rev. H. Hertzer [Herzer], who first discovered the species at Delaware, Ohio, and who cultivated that field with so much enthusiasm and success, changed his residence, and the exposures of Huron shale in central Ohio have been of late neglected. * * * *

"I have seen in some of the concretions broken open by Mr. Hertzer at Delaware traces of a plate nearly two feet in diameter, etc."[1]

Aspidichthys clavatus was described by Dr. Newberry from the Huron shale at Delaware, Ohio,[2] and *Onychodus ortoni* from the Huron shale of Perry Township, Franklin County, Ohio.[3] In addition, Dr. Eastman lists *Xenodus herzeri* (Newb.) from the Huron shale of Ohio.[5] From the sandstones of the upper Portage, near Varysburg in Wyoming County, western New York, Prof. H. S. Williams collected a specimen which he referred "provisionally to *Aspidichthys clavatus* Newberry."[5]

A recent letter from Mr. Herzer states that the specimens of fossil wood were collected by him from septaria, in the black shale near Delaware, and to the southward, before the Geological Survey was organized. "Newberry found them in my yard and he sent them to Mr. Dawson who named them Dadoxylon Newberryi."[6] In a later letter Mr. Herzer wrote that "a large portion of a trunk I saw at the first bend of the river just below Delaware with many attached Lingula. All the nicely silicified Dadoxylon I found in neglected fields, some in septaria. Most of them as thick as a man's body and most of them from between Delaware and Columbus."[7]

Specimens of fossil wood from the Geological Museum of Ohio State University, some of which, according to Dr. Orton, were from the Ohio shale of central Ohio near Columbus and Dublin, and others from the drift were sent Mr. David White, who has written as follows concerning them: "Thin sections have already been cut from the woods; a few of the latter are too far decayed or too much compressed to be identified. A cursory glance at the others shows that they represent the Dadoxylon newberryi type, that is, that they belong to the genus Callixylon, which, so far as I am able to learn, is characteristic of the Devonian.

"Whether the material referred to newberryi should be differentiated into more than one species, and whether such divisions of the group will, if established, be found characteristic of different stages of Devonian,

[1]Mon. U. S. Geol. Survey, Vol. XVI, 1889, p. 64.

[2]Geol. Surv. Ohio, Vol. 1, pt. 2, Palæontology, p. 324. Also see Mon. U. S. Geol. Survey, Vol. XVI, p. 73.

[3]Mon. U. S. Geol. Survey, Vol. XVI, p. 72.

[4]N. Y. State Mus., Mem. 10, 1907, p. 18.

[5]Bull. U. S. Geol. Survey, No. 41, 1887, p. 43.

[6]Letter of March 13, 1912.

[7]Letter of April 9, 1912.

can only be determined by very careful study of the materials, which I am not at present able, for lack of time, to carry on."[1]

Dr. Eastman on Fossil Fish of Ohio Shale.—It has been stated that the fossil fish of the Ohio shale are called Devonian because the shale has been referred to that system. In order to settle this point Dr. Charles R. Eastman, the well-known authority on Paleozoic fishes, was asked for his opinion. Dr. Eastman has written as follows:

"Your letter of the 22d inst. has been duly received, and in reply would say that in regard to the evidence afforded by fossil fishes as to the age of the Ohio shale, it seems to me that this is preponderatingly in favor of assigning the beds in question to the Upper Devonian, rather than to the Lower Carboniferous.

"Much significance attaches to the fact that the fish-fauna of the Ohio shale is characterized by an extraordinary development of Dipnoans, as represented by the order Arthrodira (*Coccosteus*, *Dinichthys*, *Titanichthys*, etc.); and in other parts of the world, notably in Scotland, northern and central Eruope, this order is restricted to the Devonian. In addition, the detached dental plates of the type described as *Ctenodus wagneri* Newb. are comparable to the jaw-parts of *Dipterus*, *Sagenodus*, *Ctenodus*, *Ganorhynchus*, *Palædaphus*, etc., that occur abundantly in the Chemung-Catskill of New York and Pennsylvania, and in the Upper Devonian of Belgium. Again, the presymphysial teeth of *Onychodus ortoni* Newb., from the Huron shale of Franklin County, Ohio, are evidently related on the one hand to the Mesodevonian *O. sigmoides*, and the Neodevonian *O. hopkinsi* on the other. The genus ranges throughout the Devonian in Europe, but is not known to persist into the Carboniferous.

"Taken together, the facts that Arthrodires predominate, and that Dipterine dental plates as well as certain typically Devonian genera like *Onychodus* and *Phœbodus* are present in the Ohio shale fauna, are of considerable weight in determining the age of the beds carrying this fauna. As for the forms of shark life taking part in the assemblage, these are of very primitive nature, and may readily be imagined as ancestral to the numerous and diversified series of Elasmobranchs which blossomed forth in the Lower Carboniferous. *Cladoselache*, by reason of its generalized organization, might be expected to appear earlier than the host of Mississippian sharks, and those from corresponding European horizons, which may all have been derived from some such progenitor as this. Under the names of *Cladodus* and *Ctenacanthus* have been described various detached teeth and spines, which are probably to be referred to *Cladoselache*, but the occurrence of similar detached remains in later deposits cannot be relied upon as a safe basis of correlation. This for the reason that widely different families of

[1]Letter of April 2, 1912.

cartilaginous fishes may nevertheless be provided with similar forms of dentition and dermal defenses.

"Finally, whatever weight may be assigned to negative evidence, one must not overlook the fact that Palæoniscid remains, such as constitute so marked a feature of the Lower Carboniferous fish-fauna of other regions, are conspicuously absent from the Ohio shale. This formation contains no typically Carboniferous genera, but on the other hand does contain four typically Devonian genera, to wit: *Phœbodus, Coccosteus, Dinichthys* and *Onychodus*."[1]

Calamites in Ohio Shale.—In the summer of 1911 Dr. Kindle found *Calamites inornatus* Dn. in the Huron shale of Huron River, near Milan, Ohio, the type specimen of which came from the Genesee shale of Cuyuga Lake, New York. Dr. Kindle writes that this specimen came from "a few feet above the base of the section which is exposed" near Milan.[2] The specimen was studied by Mr. David White, who wrote Dr. Kindle as follows:

"I have examined with great care and interest the fossil plant from the Huron shale, near Milan in northern Ohio. The fossil comprises a long fragment of the trunk of the type described by Sir William Dawson as *Calamites inornatus*. On examination I find the species to present the essential character of Nathorst's genus *Pseudobornia*, which is typical of the Pseudoborniales — an order that probably is ancestral to both the Sphenophyllales and Calmariales * * * *

"The specimens, originally described by Dawson, are said to have been obtained from the Genesee shale along the shore of Cayuga Lake in New York. I have examined similar material collected by Prof. C. S. Prosser from the upper part of the Genesee shale at Blacksmith's Gully, near Bristol Centre, Ontario County, New York, and from Seneca Point on the west shore of Canandaigua Lake. It is represented in other collections by many specimens from the Genesee shale, from Mt. Morris, New York, and other localities. The form—probably identical with *Pseudobornia inornata*—is said to have been collected from shales referred to the Hamilton group at Livonia, New York. Other material probably belonging to the same genus but concerning whose specific identity there remains doubt on account of the lack of characteristics in ordinary stem fragments, is said to have come from the Marcellus at Collingwood, Canada, and 18-Mile Creek, in New York.

"In its typical form the species is—so far as I am aware—characteristic of the Genesee shale."[3]

Specimens of *Calamites* are occasionally found in the lower part of the Ohio shale in central Ohio, in that part of the formation in which the concretions occur that contain *Dinichthys* and *Dadoxylon*. Some of

[1]Letter, October 28, 1912.
[2]Letter of April 8, 1912.
[3]Letter of December 18, 1911.

these specimens together with an entirely different form were sent Mr. David White, who has written as follows concerning them:

"One of the carbonized plant fragments is entirely strange to me. The other two appear on first inspection to represent Dawson's Calamites inornatus from the Huron in Ohio and the Genesee in New York, though I cannot be sure of the specific identity until the specimens are very carefully compared side by side. It is not improbable that the inornatus type ranges somewhat above the Genesee in New York, and that it may even ascend into the Chemung, though I have at present no conclusive evidence to show so wide a range for this species."[1] Dr. Dawson gave the distribution and range of this species as Middle Devonian of Cayuga Lake, New York, and Kettle Point, Ontario, Canada, and Lower Devonian of Gaspé, Canada.[2]

Protosalvinia of Ohio Shale.—Certain layers in the lower part of the Ohio shale in central Ohio, but in that portion of the shale in which the concretions containing *Dinichthys* and *Dadoxylon* occur, contain immense numbers of the spores named *Protosalvinia huronensis* by Dawson. According to Dr. Dawson, Professor Orton sent specimens of these spores to him "from the Erian shales of that State [Ohio], which on comparison seemed undistinguishable from *Sporangites* [*Protosalvinia*] *Huronensis*."[3] These spores have been reported and described by Dr. John M. Clarke from the Marcellus and Genesee shales of Ontario County, New York,[4] and Prof. Henry S. Williams reported "*Sporangites* [*Protosalvinia*], the same forms as those of the Ohio black shales" from the Genesee shale near Attica, Wyoming County, New York.[5] Other specimens of *Sporangites* were recorded by Professor Williams in this Bulletin from the recurrent black shales in the Portage formation of the Genesee section. Large numbers of spores, apparently of *Protosalvinia*, occur in certain layers of the black shale of the Huron in northern Ohio.

Dr. Orton on Plant Fossils of Ohio Shale. — Dr. Orton wrote as follows concerning the occurrence of plant fossils in the Ohio shale:

"Fossil wood, derived from ancient pine trees of the genus *Dadoxylon*, is quite common in the lower beds (Huron). The wood is silicified and the original structure is admirably preserved. This wood is sometimes found, like the fish remains already noted, at the hearts of the concretions, but occasionally large sized blocks are found free in the shale. On account of its enduring nature it is often found in those beds of glacial drift that have been derived largely from the destruction of the shales.

"Strap-shaped leaves, presumably of sea-weeds, are occasionally found upon the surface of the shale layers. Sometimes they form thin

[1]Letter of April 2, 1912.
[2]Geol. Survey Canada, Fossil plants Devonian and Upper Silurian formations Canada, 1871, p. 25.
[3]The Geological History of Plants, 1888, p. 51.
[4]Am. Jour. Sci., 3d ser., Vol. XXIX, 1885, pp. 285, 286.
[5]Bull. U. S. Geol. Survey, No. 41, 1887, p. 32.

layers of bright coal which deceive the ignorant. Fossil rushes, of the genus Calamites, are also occasionally met with.

"But the forms already named are of small account, so far as quantity is concerned, when compared with certain microscopic fossils that are, with little doubt, of vegetable origin, and which are accumulated in large amount throughout the black beds of the entire shale formation, composing, sometimes, a notable percentage of the substance of the rock, and apparently giving origin, to an important extent, to the bituminous character of the beds."[1]

Professor Branson on Fossils of Ohio Shale.—Dr. Branson searched carefully in the Ohio shales of northern Ohio for fossils, which he found at twelve horizons. Twenty feet from the bottom he found "a thin bed of shale that contains numerous specimens of *Lingula spatulatus* [*spatulata* Van.]" and also large specimens of it occur abundantly "about sixty-five feet below the Bedford."[2] Professor Schuchert gives the range of this species as Genesee and Portage, and some of the localities as "Lodi, Seneca Lake [Genesee shale], etc., New York; Portage group at Ithaca, New York (Williams); Erere, Province of Para, Brazil; Urals of Russia."[3] Professor Branson wrote as follows concerning the concretions:

"From the bottom of the shales to at least one hundred feet from the bottom there are large concretions, in some places in great abundance, and the nucleus of perhaps one in every hundred of these is a dinichthyid bone. The first time that the writer worked along the Huron River he found four or five fossiliferous concretions in five hours. About the same results have been obtained by working along the river once a year. Seven or eight species have been found but the remains are too incomplete to justify descriptions of new species. *Dinichthys hertzeri* and *Dinichthys intermedius* are the only described species that have been recognized."[4]

He stated that:

"Invertebrate fossils are most abundant in the upper four feet of the shales. Twenty-five or thirty species occur here, mostly of brachiopods, pelecypods, and gastropods. This horizon is fossiliferous in every locality where the writer has observed it and the only invertebrates from below are lingulas and one cephalopod."[5]

Professor Branson kindly gave the writer several of the localities where he had collected this upper fauna. They were visited during the summer of 1912 and it was found that this fossiliferous zone is the one in the basal deposits of the Bedford formation. At one locality, where

[1]Geol. Surv. Ohio, Vol. VI, 1888, p. 30; and ibid., Vol. VII, 1893, pp. 25, 26.
[2]Univ. Missouri Bull., Science ser., Vol. II, 1911, pp. 24, 26.
[3]Bull. U. S. Geol. Survey, No. 87, 1897, pp. 253, 254.
[4]Univ. Missouri Bull., Science ser., Vol. II, p. 25.
[5]Ibid., p. 26.

a section could be measured, the fossiliferous zone is about one foot above the top of the Cleveland shale.

Under the heading of "Correlation" Professor Branson has written as follows concerning the faunas of the Ohio shales:

"There are no Mississippian elements in the faunas as far as they have been investigated and this fauna from the very top is characteristically Devonian. As this region had free communication with the east and probably with the west in early Mississippian time the faunas would have had a strong Mississippian element if they had been of that age.

"The Hamilton age of the Olentangy shales seems to be established, and as the top of the Ohio shales bears a distinctly Devonian fauna, and as fish remains that are found no place outside of the Devonian are preserved throughout their thickness, it seems that the shales must be classed as Devonian and younger than the Hamilton. That the overlying Bedford shales are Devonian cannot be so positively affirmed. As there is no break in sedimentation from Ohio to Bedford and evidence from the fossils is negative, there seems to be no good reason for placing the dividing line at this contact. In as far as stratigraphic relations are concerned, the line would be drawn more appropriately at the contact of the Bedford and overlying Berea."[1]

It is to be noted that the fauna which Professor Branson located very near the top of the Ohio shale is in reality the Bedford fauna. This change in stratigraphic position, however, does not affect his conclusion that the Ohio shale is of Devonian age; but does decidedly strengthen his opinion that the Bedford also belongs in the Devonian.

Finally under the heading "Conclusions" are the following statements by Professor Branson:

"West of Elyria the Ohio shales have a distinctly Devonian fauna at the top and must be classed as Upper Devonian.

"The Bedford shale has its closest relationship with the Devonian and should probably be classed as Devonian."[2]

Professor Herrick and Dr. Girty on Devono-Carboniferous Line. — Prof. C. L. Herrick's opinion that the fauna at the base of the Bedford formation in central Ohio is Devonian is well known.[3] He stated that at this horizon is "a considerable series of fossils forming a decidedly Devonian assemblage. More remarkable still, the specific resemblances are unquestionably with Hamilton (in the broad sense) rather than the Chemung fauna."[4]

Dr. Girty has also stated that this Bedford fauna is quite distinct from any of the Mississippian ones, and favored calling the base of the

[1]Ibid., pp. 27, 28.
[2]Ibid., p. 28.
[3]Bull. Denison Univ., Vol. IV, 1888, pp. 108, 109, pl. 9.
Geol. Surv. Ohio, Vol. VII, pt. 2, 1895, pp. 506-508, pl. 20.
[4]Geol. Surv. Ohio, Vol. VII, p. 507.

Berea formation the beginning of the Carboniferous. He wrote as follows: "It is probable, however, that the Mississippian is initiated with the Berea grit, because the Bedford fauna comprises a well-defined group of species, quite distinct from any of the Waverly or Mississippian faunas. The lower Cuyahoga fauna, so far as it is known, is allied to that of the middle and upper portion. The supposed equivalent of the Berea grit in northwestern Pennsylvania contains a fauna which is without much question of a Mississippian type, and furthermore, both theoretically, and practically for mapping purposes, the Berea grit is a satisfactory bed with which to initiate the Carboniferous series."[1]

Since the above was written the writer has had the opportunity of reading an interesting paper by Dr. Girty on "The Geologic Age of the Bedford Shale of Ohio," which will be published at an early date in the Annals of the New York Academy of Sciences. More than 40 species and varieties from the Bedford are listed in this article, the closing paragraph of which is as follows:

"Therefore, while the weight of the evidence is not entirely cast on one side of the question, I believe that so far as the facts are known they indicate the line at the base of the Berea sandstone as the proper position of the Devono-Carboniferous boundary in northern Ohio. This is because that boundary is marked by an unconformity, by the presence of a basal sandstone and by a pronounced faunal change, such that while the fauna of the Berea (Corry) sandstones has a distinctly Carboniferous facies and is probably to be correlated with the Kinderhook group of the Mississippi Valley, that of the Bedford shale, though its stratigraphic position is above the typical Chemung, has, in connection with the rest of the Bradford group, a distinctly Devonian facies."

Opinions of Drs. Ulrich and Kindle.—While this bulletin is passing through the press the August number of the American Journal of Science has appeared containing two important papers by the above mentioned authors, concerning the age of the Ohio shale. Dr. E. O. Ulrich's article is entitled "The Chattanoogan Series with Special Reference to the Ohio Shale Problem."[2] Since it is only the views concerning the Ohio shale that are germane to this report, the other subjects discussed in the article will not be mentioned. Dr. Ulrich definitely stated his opinion in the following language:

"Beginning with Newberry in 1870 and continuing to the present day, all geologists who have worked on this part of the Ohio section have placed the Chagrin *above* the Huron. I insist that this relation of the two formations has never been established, and that most probably the opposite condition obtains; in other words, that the Huron is

[1]Proc. Washington Acad. Sci., Vol. VII, 1905, p. 6.
[2]Loc. cit., 4th ser., Vol. XXXIV, pp. 157–183.

younger, and not older, than the Chagrin. Incidentally it will appear that the beds beginning with the concretionary *Dinichthys herzeri* zone (which usually forms the lower part of the Huron) and ending with the top of the Cleveland shale, constitute a single broadly conceived and diastrophically unbroken formation, or a group of three lithologically distinguishable members, which overlaps eastwardly over the edge of the westwardly diminishing wedge of Chagrin shale."[1] And again he wrote:

"In further explanation of my attitude respecting the age of the Chattanoogan it should be added that until it is actually proved that the Chagrin belongs between the Cleveland and the Huron and not, as I believe, beneath both, I must insist that the Waverlyan begins in Ohio with the *Dinichthys herzeri* zone of the Huron."[2]

Dr. Kindle's article on "The Stratigraphic Relations of the Devonian Shales of Northern Ohio" is based on careful field work in this State and accompanied by a chart of local sections across northern Ohio. He takes up the overlap hypothesis and discusses in detail "The grounds on which the overlap theory rests as applied to the Cleveland and Huron shales"[3] and reaches the following conclusion:

"The products of wave action now in progress upon a retreating coast line composed of Chagrin shale may be seen along the Lake Erie shore west of Rocky River, where immense quantities of pebbles, both large and small, have been made from the sandstone bands of the Chagrin shale. With this demonstration of what wave action actually produces in the shape of coarse materials when working on the Chagrin shale, the case of the overlap theorist falls to the ground unless he can show a basal conglomerate such as must have resulted from the advance of the sea across these beds. The work of various geologists on the northern Ohio section makes it very certain that there are no such beds. We can, therefore, only conclude that the assumed overlap never occurred."[4]

Dr. Kindle calls particular attention to the cone-in-cone lenses in the Cleveland shale and the spherical concretions in the lower part of the Ohio shale and proposes "to limit the term Huron shale to those beds of the Ohio shale exposed on the Huron River, at Rye Beach and elsewhere, in which the spherical concretions occur and the Cleveland shale to the higher beds in which they do not occur and in which the cone-in-cone structure does occur."[5]

One section considers the "Structural Features" and another the "Age of the Huron shale." In the latter section he considers the plant, invertebrate and vertebrate fossil evidence and writes as follows:

[1]Ibid , p. 159.
[2]Ibid., p. 162.
[3]Ibid., p. 190.
[4]Ibid., p. 205.
[5]Ibid., p. 199.

"The report of David White on some well-preserved plant remains collected from beds within 10 feet of the lowest exposures of the Huron shale on the Huron River are of considerable interest in this connection. It is as follows:

" 'I have examined with great care and interest the fossil plant from the Huron shale, near Milan in northern Ohio. The fossil comprises a long fragment of the trunk of the type described by Sir William Dawson as *Calamites inornatus* * * *.

" 'In its typical form the species is—so far as I am aware—characteristic of the Genesee shale.' This plant is an abundant fossil in some parts of the Huron shale, although generally found in a fragmentary condition as though transported for a distance. It outnumbers all other fossil plants combined, if we except *Sporangites*, which are found in the Huron. The testimony of Mr. White that this dominant fossil plant is characteristic of the Genesee shale and is not known to occur above it should have much weight in establishing the Devonian age of the shale and the untenable position of the advocates of the overlap hypothesis.

"The invertebrate fauna of the Huron shale, like that of most black shales, is very sparse indeed. Only one brachiopod with a general distribution has been observed. This is *Lingula ligea*, which has been found at Rye Beach and other localities where the lower beds of the Huron are exposed. This shell has a recorded range from Hamilton to Portage. The collections of the writer from the type region of the Huron shale include, in addition to Lingulas, a well-preserved Paleoneilo. This shell is closely allied to if not identical with the Hamilton species *Paleoneilo tenuistriata*. It was collected from a gray band within five feet of the base of the Huron as exposed on Huron River. Another molluscan form collected from the Huron at Rye Beach is a Macrocheilus. The surface features are not preserved but the shape of the mould indicates a species closely allied to if not identical with *Macrocheilus hamiltonœ*.

"The Huron and Cleveland shales together afford a rather long list of fishes. But only a small number of these are known elsewhere. Concerning the evidence of this class of fossils it is sufficient to state here that Eastman, Hussakof, and Branson, the three paleontologists who have in recent years given most attention to the Ohio group fishes, agree in considering these fossils to represent a Devonian horizon."[1]

Finally, the closing section of this article deals with the "Upper limit of the Devonian shales" and Dr. Kindle concludes as follows:

"This earliest appearance in the Ohio section of red and chocolate-colored sediments in the Bedford shale indicates a change in the character and conditions of sedimentation of a more profound character than any which had previously occurred in the region since the cessation of

[1]Ibid., pp. 209, 210.

limestone sedimentation. This type of sedimentation is terminated throughout northern Ohio by a very marked unconformity which intervenes between the Bedford shale and the Berea sandstone. The logical place at which to draw the Devonian-Carboniferous boundary in northern Ohio appears to the writer to be the horizon of this unconformity. The fauna of the Bedford shows a Devonian facies with the possible exception of *Syringothyris*, but this genus can no longer be regarded as strictly limited to the Carboniferous. The 'Corry' sandstone of northwestern Pennsylvania, which follows the Bedford horizon and is the equivalent of the Berea, contains, according to Girty, a distinctly Carboniferous fauna. This definition of the boundary between the two systems gives as the initial formation of the Carboniferous a coarse sandstone holding an undoubted Carboniferous fauna which follows an unconformity above beds with a fauna which is more Devonian than Carboniferous in facies."[1]

[1]Ibid., p. 213.

CHAPTER VII

PALEONTOLOGY

Introduction.—It is not the intention to give in this bulletin a technical description of many of the fossils that have been collected in the formations under discussion. Such description is in course of preparation, but it is reserved for a later publication. The importance of the fossil evidence of the upper Chagrin in favor of its correlation with the Chemung formation of New York is deemed sufficient reason, however, for inserting in this bulletin six plates of Brachiopods. The following pages contain descriptions of six new forms together with notes on the Ohio specimens of the other species that are illustrated. The well known technical descriptions of the species described by Professor Hall in Vol. IV, Palæontology of New York have been drawn upon in the description of the Ohio specimens believed to belong to the same species. The figures, with the exception of six species or varieties, represent forms which are more or less characteristic of the upper Chemung of southern New York and northwestern Pennsylvania. The drawings were made by Mr. G. S. Barkentin, the accomplished delineator of the New York Geological Survey.

DESCRIPTION OF SPECIES

Dalmanella tioga (Hall) Williams var. **elmira** Williams.

Plate LXVII, figs. 1-6.

Orthis tioga Hall: Pal. N. Y. Vol. IV, 1867, p. 59, pl. 8, figs. 20-29.
Dalmanella tioga H. S. Williams: Proc. U. S. Nat. Mus., Vol. XXXIV, 1908, p. 55, pl. 3, figs. 1-5, 7, 9, 10, 12.
———— *elmira* H. S. Williams: Proc. U. S. Nat. Mus., Vol. XXXIV, 1908, p. 56, pl. 3, figs. 6, 8, 11.

Shell subquadrate, length four-fifths to five-sixths of width; hinge line a little less than half the greatest width of the shell. Ventral (pedicle) valve nearly flat, but gently convex toward the umbo with sometimes a slight mesial elevation, the umbo slightly incurved. Dorsal (brachial) valve low convex, the greatest elevation near the middle on each side of a somewhat indistinctly outlined mesial sinus. Surface

marked by radiating lines and striæ, the lines angular, more or less fasciculate and curving upwards toward the hinge line.

In the paper cited above Professor Williams revised the species described by Professor Hall as *Orthis tioga,* separated it into two species and referred them to the genus *Dalmanella.* It was stated by Hall in the original description of *O. tioga* that it is "broadly elliptical, about two-thirds as long as wide." Professor Williams wrote that the new species—*Dalmanella elmira*—"differs from *O. tioga,* as restricted, by its subquadrate form; the length is from four-fifths to five-sixths the width." The nearer equal length and width appears to be the principal difference of the form which Professor Williams has separated from *Dalmanella tioga* and named *D. elmira.* Three representative specimens of the Ohio species from Chippewa Creek were selected for illustration and their dimensions are as follows:

	Length of hinge line.	Length.	Width.	Four-fifths of width.	Five-sixths of width.	Two-thirds of width.
Figs. 1 and 2,	9 mm.	17.2 mm.	21.7 mm.	17.36 mm.	-------	14.4 mm.
" 3 and 4,	7 "	15.7 "	17.3 "	---------	14.4 mm.	11.53 "
" 5 and 6,	7 "	14.4 "	17.3 "	---------	14.4 "	11.53 "

In the above table it will be seen that four-fifths of the width of the first specimen is only slightly greater than its length, while in the second one five-sixths of the width is only 1.3 mm. less than the actual length, and in the third one five-sixths of the width is its exact length. The last column gives two-thirds of the width, which in each specimen is considerably less than its length. Since the length of the form named *Dalmanella elmira* by Professor Williams is from four-fifths to five-sixths the width it is obvious from the above table that the Ohio specimens are nearer it than the more elliptical form with a length two-thirds of the width.

Professor Williams stated that "the typical *D. elmira* is found associated with *D. tioga* in the lower part of the Chemung, but in the middle and upper part of the Cayuta member *D. elmira* becomes the prevailing species." In the Ithaca-Elmira region of southern New York Professor Williams has divided the Chemung formation in ascending order into the Cayuta shale and Wellsburg sandstone members.[1] It is perfectly clear that Hall included both the elliptical and subquadrate types in his *Orthis tioga,* as may readily be seen by an examination of his figures of the species. This is clearly indicated by Professor Williams, who states that his new species *Dalmanella elmira* "(=*Orthis tioga* Hall (in part), as represented by figs. 21, 26, 27, and 28 on Plate VIII, Pal. N. Y., IV, 1867)." Apparently the "subquadrate form" of *D. elmira* is the only important character noted by Professor Williams

[1]Watkins Glen-Catatonk folio (No. 169), Geol. Atlas U. S., U. S. Geol. Survey, 1909, Field ed., pp. 74-76.

that separates it from *D. tioga* as emended by him. This does not appear to the writer as an important and constant enough character for the creation of a new species. It is believed that there must be many connecting specimens between the two types, which it will be difficult to refer to either so-called species. It is true that the typical forms of *Dalmanella elmira* differ noticeably in shape from those of *D.tioga* sensu stricto, and for this reason the former is retained as a variety of *Dalmanella tioga*.

Horizon and Locality.—Near the top of the Chagrin formation. Chippewa Creek, where it is abundant; Bedford Glen; Big Creek.

Camarotœchia orbicularis Hall

Plate LXVII, figs. 7, 8.

Rhynchonella orbicularis Hall: Thirteenth Rept. N. Y. State Cab. Nat. Hist., 1860, p. 88.

——— ———Hall: Pal. N. Y., Vol. IV, 1867, p. 353, pl. 53, figs. 40-46.

Camarotœchia orbicularis Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 2, 1893, p. 192, pl. 57, figs. 46-48, 50.

Shell suborbicular, ventricose on the dorsal valve, width greater than the length. Ventral valve moderately convex, outline gently curving on the lateral and baso-lateral margins, the center gently depressed in a broad and strongly defined median sinus. Dorsal valve gibbous in the middle, sides curving abruptly to the ventral valve, median fold beginning above the middle of the length and becoming prominent toward the front. Surface marked by from 18 to 22 generally rounded plications, but there are subangular ones, of which 4 are usually on the mesial fold and 3 or 4 in the sinus. The dorsal valve of the specimens figured is 16.2 mm. long and 17.3 mm. wide, while the ventral valve is 15+ mm. long and 18.6 mm. wide. Another Madison road specimen is 17.3 mm. long and 20 mm. wide. One of the types from Meadville, Pa., (fig. 40, pl. 55, Vol. IV, Pal. N. Y.) is almost 19 mm. long and 20 mm. wide. As stated elsewhere the Ohio specimens were compared with types of this species in the New York State Museum and the writer considers them specifically identical.

Horizon and Locality. — Upper part of Chagrin formation. Madison-Thompson road, 3 miles south of Madison; Trumbull Creek, one-fourth mile south of Trumbull Center; Mill Creek at Eaglesville; Cherry Valley Township.

Liorhynchus ohioense n. sp.

Plate LXVII, figs. 9–13.

Shell ovate, wider than long, greatest width slightly anterior to

the middle, and compressed. Surface of mesial fold and sinus marked by from 1 to 4 broad, rounded plications which do not bifurcate, or only very near the umbo. Generally on each lateral margin 2 or 3, and occasionally more, rather narrower plications, which are more conspicuous toward the umbo and frequently are nearly indistinguishable near the anterior margin of the shell. The plications of the fold and sinus are separated by conspicuous furrows which are generally about as wide as the plications, with rather flat instead of angular bottoms. There are concentric lines, probably of growth, which in some specimens near the umbo interrupt the radiating plications. The lateral margins are mostly smooth, especially toward the anterior part of the shell. The dimensions of four specimens ranging from the largest to the smallest of those figured is as follows:

Length -----	15.2 mm.	16.6 mm.	15 mm.	12.3 mm.
Width-------	18 "	17.5 "	15.5 "	12.9 "

This form has probably been identified as *L. mesicostale* Hall, but that species is apparently a more convex shell; it has a larger number of plications on the fold and sinus which are dichotomous toward the umbo and in general are not so broad. The Ohio specimens considerably resemble medium sized ones of *L. mesicostale* Hall from the Ithaca formation at North Norwich, N. Y., which are in the American Museum; but the plications of the Ohio ones are broader and neither so high nor so angular. There is also a considerable difference in the general appearance of the specimens belonging to these two species.

Horizon and Locality.—Upper part of Chagrin formation. Just north of Gates Mill; Trumbull Creek, one-fourth mile south of Trumbull Center; Mill Creek at Eaglesville; Mill Creek east of Jefferson.

Liorhynchus globuliforme Vanuxem var. **chagrinanum** n. var.

Plate LXVII, figs. 14, 15; Plate LXVIII, figs. 1, 2.

Atrypa globuliformis Vanuxem: Geol. N. Y., Rept. Third Dist., 1842, p. 182, fig. 2.

Leiorhynchus globuliformis Hall: Pal. N. Y., Vol. IV, 1867, p. 364, pl. 57, figs. 26-29.

Liorhynchus globuliformis Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 2, 1893, p. 194, pl. 59, figs. 23-27.

Leiorhynchus globuliforme Schuchert: Bull. U. S. Geol. Survey, No. 87, 1897, p. 236.

Shell large, gibbous and usually the length slightly greater than the width. Medial fold and sinus marked by rather coarse and generally rounded plications that are most conspicuous toward the front of the

shell, of which there are 3-5 in the sinus and 4-6 on the fold. Lateral margins usually smooth; but occasionally showing faint plications near the fold or sinus. There are strong concentric lines or wrinkles of growth. Specimens are all internal impressions and the dorsal valves show a distinct median septum. An average specimen is 25.8 mm. long and 24.4 mm. wide. The one represented by figs. 14 and 15 on plate XXVIII, which is somewhat crushed laterally, is 23.5 mm. long, 19 mm. wide and 20 mm. thick. A broad and large specimen is 30 mm. long and 29 mm. wide. The specimen of *L. globuliforme* represented by fig. 26 of plate 57 in the New York Palæontology is 21.8 mm. long and 21.7 mm. wide. The one represented by fig. 27 on the same plate is 24.1 mm. long and 21.2 mm. wide, while fig. 28 is 23.8 mm. long with a probable thickness of 20.6 mm.

The very gibbous character of these shells apparently separates them from *L. mesicostale* Hall and allies them with *L. globuliforme* Van. They are narrower in proportion to their length than specimens of *L. globuliforme* collected near Port Crane, N. Y., where in certain layers this species is very abundant. On account of this and some other not very striking differences the Ohio specimens have been given the varietal name of *chagrinanum*, which indicates the formation in which they occur.

Horizon and Locality.—Upper part of Chagrin formation. Madison-Thompson road, 3 miles south of Madison; Grand River, 2 miles south of Madison.

Spirifer disjunctus Sowerby.

Plate LXVIII, figs. 3-6.

Spirifera disjuncta Sowerby: Trans. Geol. Soc. 2d. ser., Vol. V, 1840, pl. 53, fig. 8; pl. 54, figs. 12, 13.
Spirifer disjunctus Murchison, deVerneuil and Keyserling: Geol. Russia, Vol. II, 1845, p. 157, pl. 4, fig. 4.
Spirifera disjuncta Hall: Pal. N. Y., Vol. IV, 1867, p. 243, pl. 41, figs. 1-19; pl. 42, figs. 1-20.
Spirifer disjunctus Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 2, 1893, pp. 21, 24, 27, 37, 49, pl. 30, figs. 14, 15, 17.

Shell variable in shape ranging from semicircular to semioval; the hinge line as long as the greatest width of the shell and on some specimens the cardinal angles extend into long attenuated points. Ventral valve convex, sinus rather deep, rounded in the bottom and the margins clearly defined. Beak elevated, moderately incurved over the area, which is flat or concave and of variable height. Dorsal valve not so convex as ventral, mesial fold distinctly defined, of moderate elevation and convexity. Surface marked by from 20 to 25 or more

simple, mostly rounded, but with some subangular plications, on each side of the fold and sinus. The fold and sinus are each marked by 12 or occasionally more plications. The plications are rather wider than the interspaces. When the shell surface is well preserved it shows fine concentric lines and one of the best exteriors shows small and rather numerous pustules. Length of ventral valve represented by fig. 3, 25 mm., width about 35 mm., length of dorsal valve of same specimen 20.5 mm. Length of dorsal valve represented by fig. 6, 20 mm., width 37 mm. on hinge line exclusive of spine, which is 10.5 mm. long on side on which it is preserved.

The hinge area of the Ohio specimens is not so high as on part of the New York ones with which they were compared. They agree closely, however, with specimens of this species from Chautauqua Creek in southwestern New York in height of hinge area, width of shell, number and strength of plications on fold and sinus as well as on the sides of the shell. There appears to be no question as to the identity of the Ohio specimens with *Spirifer disjunctus* Sowb.

Horizon and Locality.—Upper part of Chagrin formation. Chippewa Creek; Brandywine Creek; Bedford Glen; Cherry Valley Township; Mill Creek east of Jefferson; Crooked Creek; road 2 miles east of Trumbull Center; Trumbull Creek, one-fourth mile south of Trumbull Center; Madison-Thompson road, 3 miles south of Madison; Big Creek.

Reticularia præmatura (Hall) Schuchert.

Plate LXVIII, figs. 7, 8.

Spirifer præmatura Hall: Proc. Am. Philos. Soc., Vol. X, 1866, p. 246.

——— ——— Hall: Pal. N. Y., Vol. IV, 1867, p. 250, pl. 33, figs. 31-35.

Reticularia præmatura Schuchert: Bull. U. S. Geol. Survey, No. 87, 1897, p. 344.

Hinge line shorter than the width of the shell and cardinal angles rounded. Ventral valve moderately convex with a shallow sinus which is rather broad toward the front with margins not strongly marked. Dorsal valve moderately convex with an indistinctly defined mesial fold which is broad and more conspicuous toward the front of the shell. Surface not plicate; but marked by rather prominent concentric ridges and furrows and numerous coarse radiating lines which are often continuous but most conspicuous on the concentric ridges. Length of ventral valve 20.7 mm., greatest width of one-half of it 12 mm., indicating a width of 24 mm. Length of dorsal valve 20 mm., greatest width 28 mm.

These specimens were compared with types of this species from Meadville, Pa., which are in the New York State Museum, and found to agree in all important characters.

Horizon and Locality.—Upper part of Chagrin formation. Brandywine Creek; road 2 miles east of Trumbull Center; Trumbull Creek, one-fourth mile south of Trumbull Center; Mill Creek at Eaglesville; Madison-Thompson road, 3 miles south of Madison; Big Creek.

Cyrtia alta Hall.

Plate LXIX, figs. 1-4.

Spirifera alta Hall: Proc. Am. Philos. Soc., Vol. X, 1866, p. 246.

——— ——— Hall: Pal. N. Y., Vol. IV, 1867, p. 248, pl. 43, figs. 1-8.

Cyrtia alta Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 2, 1893, p. 42, pl. 26, figs. 1-5; pl. 39, figs. 37, 38.

The majority of the specimens collected show only the cardinal area of the ventral valve with an occasional one showing more or less of the ventral surface of the shell. In soft shales badly crushed and broken specimens of both valves have been seen. Ventral valve is extremely elevated and subtriangular. Hall gave the height and width about as three to five. The specimens represented by figs. 2 and 4 have very nearly this proportion, while the one represented by fig. 3 is nearer the proportion of two to three. The hinge area is very large, triangular, acute at point, inclining forward and on the best preserved specimens showing vertical lines as well as transverse ones. Hall described the area as "strongly striated vertically," and the fissure or delthyrium as "large but comparatively narrow, being more than twice as high as its width at the base." This is true of these specimens since the delthyrium of the one represented by fig. 2 is 15.3 mm. wide at its base and 37.6 mm. high and on the one represented by fig. 4 it is 16 mm. wide and 47 mm. high. The delthyrium is closed by a concave, transverse delthyrial plate for about two-thirds of its length from the apex. The length of this delthyrial plate on the specimen represented by fig. 3 is 25 mm. and of the delthyrium 36 mm.; on the one represented by fig. 2 the plate is 26 mm. long and delthyrium 38 mm., and the same portions of the one shown by fig. 4 are respectively 33.5 mm. and 48 mm. Margins of delthyrium grooved for the delthyrial plate. Sinus broad, rounded in bottom, extending entire length of valve and plicated, the ribs frequently indistinct except toward its front. An internal impression of a ventral valve (fig. 1) shows 14 or more rounded plications on one side toward the anterior

margin of the shell and conspicuous concentric ridges and furrows. The sinus is also faintly plicated toward the front and both the diductor and adductor muscular scars are clearly outlined. The front margin of the valve has a sinuate outline like fig. 4 of pl. 43, Vol. IV, Pal., N. Y. The dimensions of three specimens are as follows:

Length of ventral valve	(fig. 1)	41.5 mm.	
Height of hinge area	" 2	38 "	
Width on " "	" 2	60 "	(about)
Height of " "	" 3	37 "	
Width on " "	" 3	52 "	
Height of " "	" 4	48 "	
Width on " "	" 4	76 "	

These specimens were compared with the Meadville types in the New York State Museum, with which they closely agree in all important characters, so that there is apparently no question as to their specific identity.

Horizon and Locality.—Upper part of Chagrin formation. Chippewa Creek; Madison-Thompson road, 3 miles south of Madison; Big Creek.

Syringothyris texta (Hall) Schuchert var. **chemungensis** Cushing n. var.

Plate LXX, figs. 1-5.

Spirifer textus Hall: Tenth Rept. N. Y. State Cab. Nat. Hist., 1857, p. 169.

———— *carteri* Meek: Geol. Surv. Ohio, Paleontology Vol. 2, 1875, pl. 14, fig. 7.

Syringothyris texta Schuchert: Ninth Ann. Rept. N. Y. State Geol., 1890, p. 34.

As stated in another part of this bulletin (see pp. 761–764) the best specimens of this variety were collected by the late Prof. Samuel G. Williams and later studied by H. P. Cushing, when a graduate student at Cornell University, under the direction of Prof. Henry S. Williams. The following description is quoted from Professor Cushing's manuscript:

"Specifically it is very close to *Syringothyris textus* Hall, and to the form described by Meek from Ohio as *S. carteri* (Pal. Ohio, Vol. II, p. 286) which he states to be intermediate between typical *S. textus*, and *S. carteri*. My specimens are of a medium, or rather large size, length about one-half the width, and width about twice the height of the area. Dorsal valve of the usual shape in this genus, mesial fold rather prominent, crossed by concentric wrinkles in old shells, and showing a mesial depression extending half way to the base;

beak small with narrow area, and both strongly incurved. Ventral valve sloping laterally from the beak at angles of from 100° to 135°; mesial sinus rather deep, smooth except for concentric wrinkles in old shells, and projecting beyond the valve to fit into a corresponding sinus in the dorsal valve, area high, faintly vertically and transversely striate, nearly flat or slightly arched near the beak, with its lateral margins rather sharply defined, and curving slightly to the hinge; fissure narrow for this genus, varying from two-sevenths to one-fifth as wide as the hinge line, averaging about two-ninths; width of fissure about one-half its height; closing its upper part is a transverse shelly plate, rather deep seated, nearly flat, extending from one-fourth to one-half the length of the fissure, and terminating in a short, tubular projection. Surface of both valves marked by 18 to 24 (generally 20) broad, rounded plications, on each side of the fold and sinus, crossed by fine concentric striæ, and occasional concentric lines of growth; a minute pitting covers the entire surface. Mesial septum extends about three-fifths the length of the ventral valve; the divaricator scars are much as represented in Meek's figure (7d, pl. XIV, Pal. Ohio, Vol. II), but vary considerably, the greatest width often being nearer the base of the scars than in that figure, and the proportions of length to breadth varying considerably. The dental plates are very long, but vary considerably, sometimes nearly enclosing the divaricator scars, sometimes not extending much over half their length, varying from 3-5ths to 4-5ths the length of the valve.

"Professor Hall distinguished *S. carteri* from *S. textus*, as having a smaller, less elevated, and more arcuate area, beak more arched, and lateral slopes of area less angular—10th Rept. State Cab. Nat. Hist. N. Y., p. 170. My specimens show considerable variation in all these respects, the lateral slopes of the area make angles of from 100° to 135°, the more common angles being 115° to 125°, the area is in general flatter and more elevated than in *S. carteri*, but there is some variation in the first respect, and much in the latter. The form is intermediate between the two, most nearly approaching *S. textus*, and with extreme forms approaching both species. It seems to differ from all others in its narrow fissure, one-half as broad as high and from one-fifth to one-fourth as broad as the hinge line, but extreme forms connect it with *S. textus* in this respect. The slight development of the tube, and the length of the transverse plate in the fissure distinguish it from *S. typa* and *S. halli* of Winchell. The generic characters are presented in a not fully developed condition. I regard it as a variety of *S. textus*, distinguished by its narrow fissure, small tube, and faintly striate area, and have called it var. *chemungensis*. I believe it to be referable to *S. cuspidatus* Martin, but have not figures and descriptions at hand for comparison."

Some of the better preserved specimens from Professor Cushing

clearly show the punctate structure of the shell, the pores of which are minute and distant, similar to those of fig. 12, pl. 27, pt. 2, Vol. VIII, Pal. N. Y. Internal impressions collected by the writer show the rather large tubular opening of the delthyrial plate similar to figs. 13 and 17 of the plate just mentioned. Specimens were examined by Dr. Kindle, Professor Weller and Dr. John M. Clarke, all of whom agreed that they belong to *Syringothyris*, so that there appears to be no question concerning the accuracy of this generic identification.

Horizon and Locality.—Upper part of the Chagrin formation, perhaps 200 feet below its top. Mill Creek, 1 mile north of Jefferson.

Ambocœlia umbonata (Con.) Hall var. **gregaria** Hall.

Plate LXX, figs. 6-9.

Orthis umbonata Conrad: Jour. Acad. Nat. Sci., Philadelphia, Vol. VIII, 1842, p. 264, pl. 14, fig. 4.

Ambocœlia umbonata Hall: Thirteenth Rept. N. Y. State Cab. Nat. Hist., 1860, p. 71.

——— ——— Hall: Pal. N. Y. Vol. IV, 1867, p. 259, pl. 44, figs. 7-18.

Orthis unguiculus Hall (non Phillips): Geol. N. Y., Rept. Fourth Dist., 1843, p. 267, fig. 5.

Ambocœlia gregaria Hall: Thirteenth Rept. N. Y. State Cab. Nat. Hist., 1860, p. 81.

——— *umbonata* var. *gregaria* Hall: Pal. N. Y., Vol. IV, 1867, p. 261, pl. 44, figs. 19-25.

Shell small and plano-convex. Ventral valve convex with high and incurved umbo and rather deep median sinus which is angular in the bottom, extending from the umbo to the front. Dorsal valve semielliptical, depressed convex, umbo scarcely elevated above the hinge line, with a distinct median sinus extending from the umbo to the front. Surface marked by fine radiating and concentric lines, the latter the more conspicuous and somewhat lamellose toward the front of the shell as seen on the dorsal valve. Length of ventral valve 5 mm., width 5 mm., length of dorsal valve 4 mm., width 5 mm.

Specimens compared with a type in the New York State Museum and there is apparently no doubt concerning their identity. The very distinct median sinus of the dorsal valve, while there is none on this valve of *Ambocœlia umbonata,* seems to refer it at once to the variety *gregaria.* Some authors consider it a distinct species instead of variety, as for example Professors Williams[1] and Schuchert.[2]

[1]Bull. U. S. Geol. Survey, No. 210, 1903, pp. 83, 86.
[2]Ibid., No. 87, p. 140.

Horizon and Locality.—Upper part of Chagrin formation. On road 2 miles east of Trumbull Center; Brandywine Creek; Cherry Valley Township.

Athyris polita Hall.

Plate LXX, figs. 10, 11.

Atrypa polita Hall: Geol. N. Y., Rept. Fourth Dist., 1843, Tables of Organic Remains No. 66, fig. 5.
Athyris ? polita Hall: Pal. N. Y., Vol. IV, 1867, p. 293, pl. 47, figs. 21-33.
Athyris polita Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 2, 1895, pl. 46, figs. 1-5.

Shell ovate, more gibbous in the anterior part. Ventral valve slightly more gibbous than the dorsal, the greatest gibbosity above the middle; an undefined sinus begins about one-third the length from the umbo, which expands and becomes deeper toward the front. On one specimen with a length of 16.5 mm. the sinus begins at about 6 mm. from the apex. The umbo closely incurved over the one of the opposite valve. Dorsal valve with greatest gibbosity a little above the middle and curving abruptly to the beak and lateral margins. A broad and undefined mesial fold marks the anterior third of the valve. Surface of well preserved specimens marked by fine close concentric lines and occasional heavy furrows and ridges, as well as rather indistinct radiating lines. Two average ventral valves have a respective length of 16.5 mm. and 16.4 mm. with a width of 15 mm. and 15.4 mm. Two dorsal valves are 16.4 mm. and 16.5 mm. long, and 15.4 mm. and 16.3 mm. wide. A ventral valve of a small specimen is 11.4 mm. long and 9.3 mm. wide, while a dorsal valve of a similar one is 9.3 mm. long and 9 mm. wide.

Specimens were compared with types of this species in the New York State Museum, with which they agree closely.

Horizon and Locality.—Upper part of Chagrin formation. Chippewa Creek; Trumbull Creek, one-fourth mile south of Trumbull Center; Cherry Valley Township; road 2 miles east of Trumbull Center; Brandywine Creek.

Chonetes minutus n. sp.

Plate LXXI, figs. 1-5.

Shell small, wider than long, hinge-line equaling its greatest width. Ventral valve moderately gibbous in the middle and flattened toward the cardinal angles. Surface marked by fine, close, usually equal radiating lines, varying from 24 to 36 on a valve and very fine, thread-like,

close, concentric ones. At least three long, slender spines on each side of the umbo originate on the cardinal margin and bend outwards. Three specimens of average size were measured which have the following dimensions, commencing with the smallest:

Length	2.2 mm.,	2.8 mm.,	3.4 mm.
Width	3.2 " ,	3.8 " ,	3.8 "

This species resembles somewhat the figures of small forms of *C. scitulus* Hall as figs. 7 and 8 of pl. 22, Vol. 4, Palæontology of New York. The type specimens represented by these figures, however, were borrowed and on comparison it was evident that the Ohio forms are decidedly smaller and quite different in some other characters. The original of fig. 7 is in the New York State Museum and came from the Chemung at Conewango, N. Y. Its length is 4.8 mm. and width 7.5 mm. Two diverging spines are shown near the cardinal angles and a third one nearer the umbo; but they are not so long and slender as on the Ohio specimens. About 15 strong lines are shown on a side, which fail before reaching the ears, and are separated by spaces two or three times their width, in which are occasional rather inconspicuous lines. These lines are different from the close, equal ones of the Ohio specimens. The original of fig. 8 is in the American Museum of Natural History and came from the Chemung of Tioga County, Pa. Its length is 6.6 mm. and width 10.4 mm., so that it is twice the size of any of the Ohio specimens. There are 25 or 26 lines on the left half of the valve, which is a ventral one, while the Ohio ones have only from 12 to 18 lines on a side, which are decidedly smaller than those of the Pennsylvania type specimen. In size this species resembles somewhat *C. lepidus* Hall, but differs in not having two strong lines on the medium part of the ventral valve outlining a sinus.

Horizon and Locality.—Chagrin formation. Run 2 miles south of Monroe Center, Ashtabula County.

Chonetes scitulus Hall.

Plate LXXI, fig. 6.

Chonetes scitula Hall: Tenth Rept. N. Y. State Cab. Nat. Hist., 1857, p. 147.

——— ——— Hall: Pal. N. Y., Vol. IV, 1867, pp. 130, 141, pl. 21, figs. 4a-f.

——— *scitulus* Beecher: Am. Jour. Sci., 3d. ser., Vol. 41, 1891, p. 357, pl. 17, fig. 14.

——— *scitula* Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 1, 1892, pl. 16, figs. (?) 3, 4, 27, 32, 40, 44.

Shell rather small, wider than long, the hinge-line sometimes not equaling the greatest width. Ventral valve moderately gibbous in the middle, regularly curving to the front and lateral margins, and abruptly depressed toward the cardinal angles, which are nearly flat. Hinge area narrow and wider in the middle. Dorsal valve concave; but the concavity less than the convexity of the ventral valve, the cardinal angles flat and the hinge area linear. Surface marked by fine, subequal lines with 15 or more near the beak, while from bifurcation and intercalation 50 or more are on the margin. The cardinal margin of the ventral valve has 2 or 3 spines on each side toward the extremities and as many more toward the beak.

The ventral valve figured has 14 lines near the beak and about 50 on the margin. There are 3 rather long and slender spines toward the end of the cardinal margin on the right side and 2 near its end on the opposite side with the base of a third one. The length of the valve is 4.3 mm. and its width 6.9. It was compared with two type specimens of the smaller form of this species. The original of fig. 7, pl. 22, Vol. IV, Pal. N. Y., from the Chemung of Conewango, New York, is 4.8 mm. long and 7.5 mm. wide, and the original of fig. 8 of the same plate from the Chemung of Tioga County, Pa., is 6.6 mm. long and 10.4 mm. wide. It will be seen that the Ohio specimen is only slightly smaller than the type represented by fig. 7, Pal. N. Y., and its surface markings agree better with the description of this species, since it has about 50 lines on the margin while the type has only about 30. The original of fig. 8 has 50 to 52 lines, and Hall's description calls for 50 to 60 on the margin.

Horizon and Locality.—Upper part of Chagrin formation. Tinkers Creek at Bedford.

Strophalosia muricata (Hall) Beecher.

Plate LXXI, figs. 10, 11,(?) 12,(?) 13.

Chonetes muricata Hall: Pal. N. Y., Vol. IV, 1867, p. 143, pl. 22, figs. 29-43.

Strophalosia ? muricata Beecher: Am. Jour. Sci., 3d ser., Vol. XL, 1890, p. 241.

Strophalosia muricata Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 1, 1892, p. 316, pl. 16, figs. 12, 16, 30, 38, 42.

Shell semielliptical, concavo-convex, hinge-line generally less than the greatest width of the shell with the cardinal angles rounded. Ventral valve moderately and regularly convex, somewhat flattened toward the cardinal angles and the front broadly rounded. The umbo generally truncated. Surface concentrically striated, with wrinkles

on the cardinal margins which become more or less obsolete on the body of the shell. Frequently 4 to 6 spines on the hinge-line on each side of the umbo and also on the folds on the cardinal margins. The spines are less abundant on the central part of the valve; but toward the front and lateral margins are a large number of slender ones. Dorsal valve moderately or deeply concave and following the contour of the opposite one. The dorsal surface is indented by fossets which produce pustules on the inner surface of the valve; but spines are not shown on specimens examined. The dimensions of the four figured specimens are as follows:

	Fig. 10	Fig. 11	Fig. 12	Fig. 13
Length	14 mm.,	18.4 mm.,	18 mm.,	19.5 mm.
Width	18.8 " ,	23.5 " ,	20.5 " ,	27.5 " .

This species was described by Hall as a *Chonetes*; but the spines on the surface of the shell separate it from that genus which has spines only on the hinge line. Some of the specimens have some resemblance to *Productella*; but the truncated umbo of at least part of the specimens has led to its reference to the genus *Strophalosia*.

The specimens figured are all internal impressions of ventral valves and resemble some figures of Hall's *Chonetes muricata*, especially fig. 34, pl. 22, Vol. IV, Pal. N. Y., and fig. 12, pl. 16, pt. 1, Vol. VIII of the same work. The shells of this genus are described as attached by the umbo of the ventral valve which is often truncated or at least marked by a cicatrix or scar of attachment. Hall's original figures, however, show two ventral valves side by side, one (fig. 35) with a truncated beak and the other (fig. 34) without any truncation or cicatrix. This difference led one paleontologist to remark that Hall had apparently included two different forms in his figures of *Chonetes muricata*. The same difference, however, is to be found in Hall and Clarke's great work on the Genera of the Palæozoic Brachiopoda where on pl. 16, pt. 1, Vol. VIII, Pal. N. Y., 1892, fig. 12 shows a ventral valve of *Strophalosia muricata* without any indication of a cicatrix, while fig. 16 gives "two views of a pedicle-valve; showing the cicatrix of attachment." This appears to indicate that these two authors did not consider the presence of a cicatrix or truncation of the umbo as absolutely necessary in order to refer a ventral valve to this genus. Dr. Ruedemann stated that the shells of *Strophalosia* are not attached during their entire life; but become so toward the adult stage so there may be younger specimens without either a truncation or cicatrix. The figures, however, of the specimens without a cicatrix in the Palæontology of New York apparently represent adult forms. The type specimen represented by fig. 34, pl. 22, Vol. IV, Pal. N. Y., was studied in the New York State Museum. It is an internal impression of a ventral valve showing bases of spines on hinge line together with some on the left side, apparently

a little below it. The spines do not look so much like those of a *Chonetes* as shown in the figure. There are small pits on the rest of the surface, but no spines.

The specimens figured were sent to Professor Grabau, who has written as follows concerning them: "As to the identification of the specimens as *Chonetes* (*Strophalosia*) *muricata* I should agree for the one marked 115 [which is from the stream in the northwest corner of Monroe Township, Ashtabula County, and is represented by fig. 10]. The others may be the same, but they appear to be larger, and do not show the indications of surface spines. However, that is the nearest that can be done, I think." The specimen from Crooked Creek, Hartsgrove Township, Ashtabula County, represented by fig. 11, closely resembled specimens of this species in the Museum of Cornell University in which identification Professor Williams concurred (see p. 298.) The specimens, therefore, represented by figs. 10 and 11 are referred to *Strophalosia muricata* and those represented by figures 12 and 13 to the same species with a (?) mark.

Horizon and Locality.—Chagrin formation. Upper part of formation on Crooked Creek, Hartsgrove Township; West Branch Ashtabula Creek, west of Richmond Center (?); eastern part Richmond Township, on tributary of East Branch Ashtabula Creek (?); south of Pennline, Pa.; Mill Creek, western part Dorset Township; West Branch Ashtabula Creek, north of Gould; northwest corner Monroe Township.

Camarotœchia contracta Hall.

Plate LXXI, figs. 14-20.

Atrypa contracta Hall: Geol. N. Y., Rep. Fourth Dist., 1843, Tables of Organic Remains No. 66, figs. 2, 3.
Rhynchonella (*Stenocisma*) *contracta* Hall: Pal. N. Y., Vol. IV, 1867, p. 351, pl. 55, figs. 26-39.
Camarotœchia contracta Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 2, 1893, p. 192, pl. 57, figs. 28-32, 49.

Shell always wider than long, abruptly and deeply sinuate on the anterior margin. Ventral valve prominent on the umbo, with beak incurved and closely appressed against that of the dorsal valve, gently declining to the lateral margins. The sinus becomes conspicuous near the center, where the shell is abruptly depressed into a broad and deep one, with sloping sides free from plications; extremely produced in front with a broad linguiform extension which fills a corresponding depression in the front of the dorsal valve. Dorsal valve rather gibbous in the middle, the mesial fold becoming prominent a little above the middle. Surface of each valve marked by from 14 to 17 angular pli-

cations on the Ohio specimens, of which 3 are usually depressed in the mesial sinus and 4 occur on the mesial fold. The 4 plications of the fold apparently originate as 2 near the umbo, which later divide, and usually toward the front the two central ones are stronger than the lateral ones. The dimensions of five of the figured specimens are as follows:

Length	9 mm.,	11.3 mm.,	12 mm.,	13 mm.,	14.6 mm.
Width	9.5 " ,	14.5 " ,	15.5 " ,	15.3 " ,	17.6 " ,

This species is distinguished by its shape (greater width than length), size, angular plications, deep sinus marked with 3, and conspicuous fold with 4 plications.

Horizon and Locality.—Chagrin formation. Chippewa Creek; Tinkers Creek at Bedford; West of Richmond Center on branch of West Branch Ashtabula Creek; on tributary of East Branch Ashtabula Creek, eastern part of Richmond Township; in Rock Creek at Rock Creek; Mill Creek, 2 miles north of Jefferson; West Branch Ashtabula Creek at first highway crossing north of Gould; stream in northwest corner of Pierpont Township; stream in northwest corner of Monroe Township; stream 2 miles south of Monroe Center.

Liorhynchus clarkei n. sp.

Plate LXXI, figs. 21-23; Plate LXXII, figs. 1-4.

Shell generally wider than long and both valves varying from convex to gibbous. Mesial fold and sinus usually clearly indicated and marked by from 5 to 7 rounded, medium sized plications, which extend from the anterior margin well toward the beak, usually bifurcating as it is approached. Generally on each side from 4 to 8 plications and on some specimens rather indistinct ones extend nearly if not quite to the lateral margins. The dimensions of six of the figured specimens are as follows:

Length	26 mm.,	23.6 mm.,	24 mm.,	24.3 mm.,	20.3 mm.,	24.5 mm.
Width	25 " ,	28.2 " ,	29.2 " ,	23 " ,	23.5 " ,	32.5 " .

This species in form and size resembles considerably *L. mesicostale* Hall; but differs from it in the conspicuous plications on the lateral margins, which in that species are smooth or obscurely marked by low obsolete folds. It also differs from *L. newberryi* Hall, which is a larger species and marked by a much larger number of rather finer and more angular plications.

Specimens were submitted to Dr. John M. Clarke, who wrote as follows: "I have examined the brachiopods you have sent in and it

seems to me that you would go amiss in regarding this as either *Liorhynchus newberryi* or *L. mesacostalis*. The species looks from the number of individuals scattered through the specimen to be very abundant, and if all the individuals hold such characters as are here presented, both as to size and in respect to plication, I should think you would be quite safe in regarding the species as new."[1] The specific name is given in honor of Dr. Clarke, the distinguished State Geologist and Paleontologist of New York.

Horizon and Locality.—Chagrin formation. Mill Creek 2 miles north of Jefferson and below the railroad bridge.

Liorhynchus ashtabulense n. sp.

Plate LXXII, figs. 5-8.

Shell wider than long. Ventral valve convex and beak rather prominent. Mesial sinus clearly outlined by a larger and more conspicuous plication on each side and containing 2 or 3 rather large, rounded plications which increase in strength toward the anterior margin. Each side marked by 2 or 3 rather indistinct plications which decrease in strength from the sinus toward the lateral margins, which are rather smooth. Dorsal valve not seen. The dimensions of the four figured specimens, commencing with the smallest, are as follows:

Length	18 mm.,	20 mm.,	20.3 mm.,	21.8 mm.
Width	18.8 " ,	22.4 " ,	23.9 " ,	22.6 " .

This species differs from *Liorhynchus mesicostale* Hall in having a smaller number of larger plications in the mesial sinus, while the sides show more distinct ones. It differs from *L. clarkei* in the smaller number of broader plications in the sinus, while in general they are less conspicuous on the sides which are more nearly smooth. Finally, it differs from *L. ohioense* in its much greater convexity, strongly outlined mesial sinus and more conspicuous as well as angular plications.

Horizon and Locality.—Chagrin formation. Run two miles south of Monroe Center.

Liorhynchus newberryi Hall.

Plate LXXII, figs. 9, 10.

Leiorhynchus newberryi Hall: Twenty-third Ann. Rept. State Cab. Nat. Hist., [N. Y.] 1873, p. 240, pl. 11, figs. 25-27.

Shell large and ventricose with a slight mesial depression on the ventral valve and corresponding elevation on the dorsal. Surface

[1]Letter of June 12, 1912.

marked by numerous, subangular, bifurcating plications which are strongest on the medisal fold and sinus, but extend well toward the lateral margins. The specimens studied have 7 or 8 plications on the fold and 8 or 9 in the sinus. Professor Hall stated that "the number of plications varies in different individuals; some specimens have only about three in the space of a fourth of an inch, on the middle of the shell; while others have from six to eight." The number of plications in that distance on the middle of the shell varies on the specimens studied from 4 to 8. Specimens on which the shell is preserved show fine, closely arranged concentric lines, especially toward the anterior margin. The larger specimen figured is 34.5 mm. long and about 32.7 mm. wide.

This species differs from the others in its greater gibbosity, larger number of plications extending almost if not quite to the lateral margins, and generally larger size.

Horizon and Locality.—Chagrin formation. Run two miles south of Monroe Center; loose in Mill Creek at Eagleville.

Productella hirsuta Hall.

Plate LXXI, figs. 7-9.

Strophomena membranacea Vanuxem (non von Buch): Geol. N. Y. Rept. Third Dist., 1842, p. 181, figs. 4, 5 on p. 179.
Productus hirsuta Hall: Tenth Rept. N. Y. State Cab. Nat. Hist., 1875, p. 175, figs. 1-3.
Productella hirsuta Hall: Pal. N. Y., Vol. IV, 1867, p. 166, pl. 24, figs. 17-29.
——— ——— Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 1, 1892, pl. 17, figs. 28, 39, 45.

Shell of medium size, semielliptical, concavo-convex; hinge-line equaling or a little less than the width of the shell. Length of shell varying from less than the width to equal to it. Ventral valve convex in the middle, gibbous on the umbo, gradually curving to the front and lower lateral margins, and abruptly depressed toward the cardinal lateral margins, which are nearly flat and auriculate. Dorsal valve moderately concave, and flattened toward the cardinal extremities. Surface marked by fine, imbricating concentric lines. On the ventral valve a row of rather long, diverging, nearly straight spines on each side on or just below the hinge-line, and nearly the entire surface covered by numerous slender, long spines, the bases of which form small elongated pustules on the surface.

The three Ohio specimens figured, which are from Tinkers Creek at Bedford, have the following measurements:

	Fig. 7 Ventral valve	Fig. 8 Dorsal valve	Fig. 9 Dorsal valve
Length	12.5 mm.,	12 mm.,	12 mm.
Width	15.5 " ,	16.5 " .	19 " .

In these specimens it will be seen that the length is less than the width of the shell. Professor Hall gave the "length and breadth about as 8 to 10 or 12, or as 9 to 11, and, from natural or accidental causes, varying to length and breadth equal." It will be seen that the ventral valve, fig. 7, has nearly the proportion of 4 to 5, which is the same as Hall's 8 to 10. The dorsal valve, fig. 9, has nearly the proportion of 2 to 3, which is the same as Hall's 8 to 12; but the impression of a dorsal valve, fig. 8, has nearly that of 3 to 4. The spines of the ventral valves are long, slender and somewhat wavy and well shown in the rock adjacent to the dorsal valve shown in figure 9. Dr. Ruedemann examined the specimens and thought that most of the spines near the hinge-margin looked like hinge spines, although one apparently came up from below. He thought the wavy appearance indicated that they were not as stiff as spines usually are and suggested that they might be bristles.

Professor Schuchert saw the Bedford specimens and first suggested to the writer that they belonged to the genus *Productella* and were like the species *hirsuta*. The types of this species are in the American Museum and the Bedford specimens were later sent to Professor Grabau, who kindly compared them with the types and wrote as follows: "The specimens labeled 122 [from Tinkers Creek at Bedford] I should refer to *Productella hirsuta*, though they are more regular and show the spines much better than the type specimens."

Horizon and Locality.—Upper part of Chagrin formation. Tinkers Creek at Bedford; Chippewa Creek.

Productella hirsuta Hall var. rectispina Hall.

Plate LXXII, figs. 11-13.

Productella hirsuta var. *rectispina* Hall: Pal. N. Y., Vol. IV, 1867, p. 168, pl. 24, figs. 30-37.

——— ——— ——— Hall and Clarke: Pal. N. Y., Vol. VIII, pt. 1, 1892, pl. 17, fig. 37.

Shell generally large, semielliptical, concavo-convex, and unequal or distorted on each side of the umbo. The length of hinge-line in proportion to width of shell and shape of the ventral and dorsal valves of this variety are similar to those of the species, which have been given in the preceding description. Surface marked by concentric wrinkles which are prominent toward the front and are especially conspicuous on and near the cardinal margins. Also the entire surface, except occasionally the umbo and more prominent portions of the valve, covered by numerous slender spines, the bases of which form small elongated pustules on the surface.

The Ohio specimens figured have the following measurements:

Length	31.2 mm.,	34.8 mm.,	35.4 mm.
Width	44.5 " ,	46.2 " ,	44. " .

Professor Hall stated that ***Productella hirsuta*** has a "length and breadth about as 8 to 10 or 12, or as 9 to 11, and, from natural or accidental causes, varying to length and breadth equal." The proportion of length to width in the first two Ohio specimens is about 8 to 11, and in the third one nearly 9 to 11, so that in this character there is close agreement. The Ohio figured specimens were compared with the types of this variety represented by figs. 31-35, pl. 24, Vol. IV, Pal. N. Y., which are in the American Museum, and they agree rather closely in the size and character of the small spines. The spines are probably a little coarser on most of the New York specimens, but the original of fig. 32 agrees closely with some of those from Ohio. The New York types are rather wider in proportion to their length than the Ohio ones; but a specimen from Meadville, Pa., identified by Hall, is almost a counterpart in size and shape of some of the Ohio specimens. The generally larger size and distortion or inequality on each side of the umbo, together with the concentric wrinkles serve to separate this variety from the species.

Horizon and Locality.—Upper part of Chagrin formation. Brandywine Creek below the fall.

EXPLANATIONS OF PLATES

PLATE LXVII

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Figs. 1–6. *Dalmanella tioga* (Hall). Wms. var. *elmira* Wms. 530

1, 2. Ventral (pedicle) and dorsal (brachial) valves of a large specimen, showing fine radiating lines and striæ and some concentric lines of growth.

3, 4 and 5, 6. Ventral and dorsal valves respectively of medium sized specimens.
All from Chippewa Creek.

Figs. 7, 8. *Camarotœchia orbicularis* Hall and Clarke 532

7. Dorsal valve with 4 plications on the fold and 8 on each side.

8. Internal impressions of ventral valve which is somewhat broken toward the beak. It shows 3 plications in the sinus and 6 or 7 on each side.
Both from Madison-Thompson road, 3 miles south of Madison.

Figs. 9–13. *Liorhynchus ohioense* n. sp. 532

9. Dorsal valve with 4 plications on fold and 2 more indistinct ones on each side.
North of Gates Mill.

10. Dorsal valve with 3 plications on the fold and 4 or 5 rather indistinct ones on the lateral margins.
Trumbull Creek.

11. Ventral (?) valve with 3 plications in the sinus (?), or two may be considered as outlining the sinus with one in it. The figure shows a fourth one on the right margin too strongly.

12. Ventral valve with 4 prominent median plications, of which two outline the sinus with two in it, or perhaps all four may be referred to the sinus. The specimens of figs. 11 and 12 from north of Gates Mill.

13. Dorsal valve with 4 plications on fold and rather strong ones on each lateral margin. Trumbull Creek, one-fourth mile south of Trumbull Center. The specimens from Trumbull Creek have more conspicuous lateral plications than those from north of Gates Mill.

Figs. 14, 15. *Liorhynchus globuliforme* Van. var. *chagrinanum* n. var..... 533

14. Internal impression of ventral valve with 3 plications in sinus.

15. Internal impression of dorsal valve of same specimen showing 4 plications on fold and median septum. Specimen somewhat crushed laterally. Madison-Thompson road, 3 miles south of Madison.

PLATE LXVII.

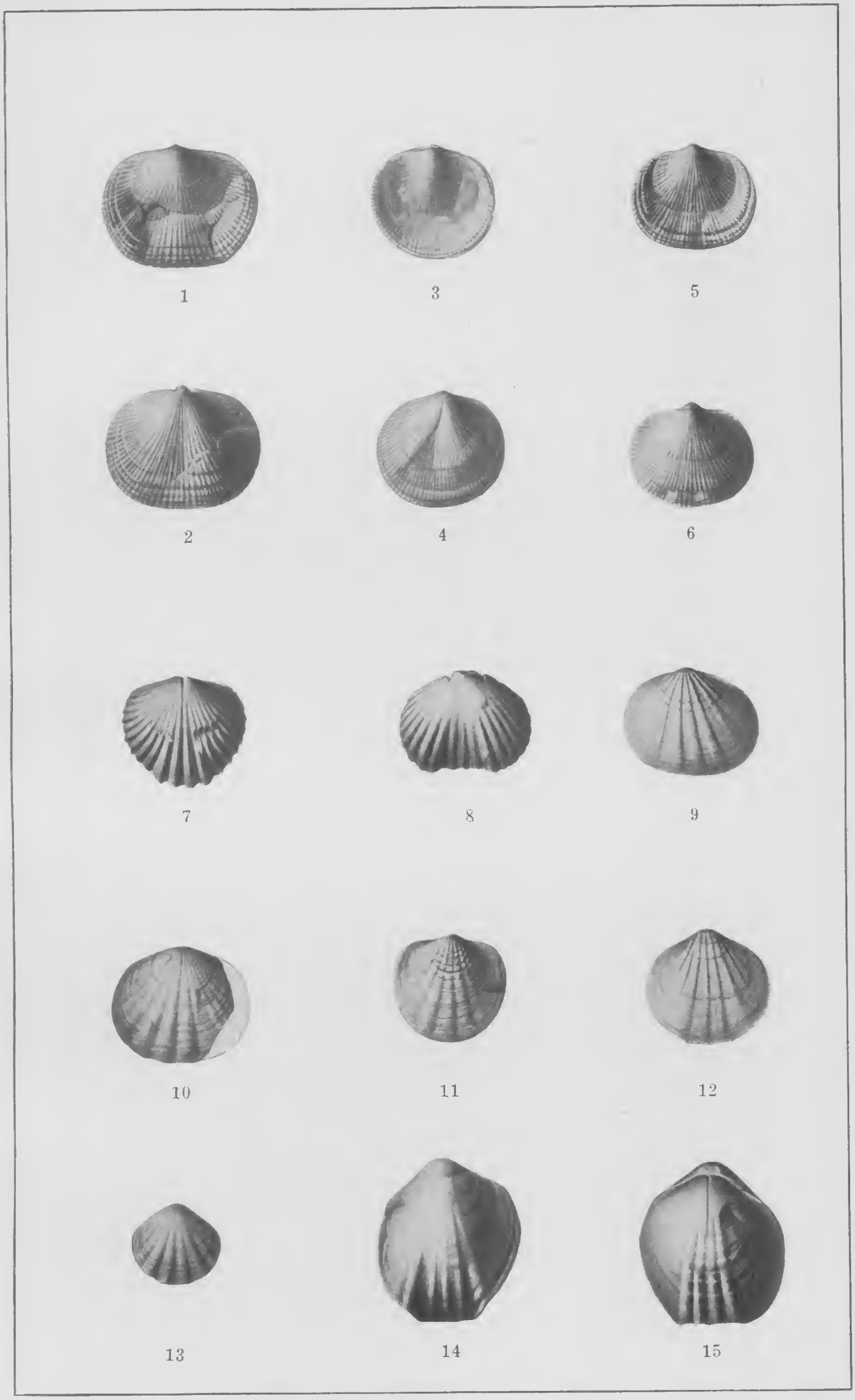

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PLATE LXVIII

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Figs. 1, 2.	*Liorhynchus globuliforme* Van. var. *chagrinanum* n. var. ------	533

1. Internal impression of ventral valve showing 4 distinct plications in the sinus, and another indistinct one on each side of it. This specimen is 26 mm. long and 25 mm. wide.
2. Internal impression of ventral valve showing 4 plications in sinus and short septum near the umbo. Entire length not shown; but it is 22+ mm. long and 25.5 mm. wide. Madison-Thompson road, 3 miles south of Madison.

Figs. 3–6.	*Spirifer disjunctus* Sowb. ----------------------------------	534

3. Ventral valve, with cardinal angles wanting.
4. Dorsal valve of same specimen showing hinge area of ventral valve. Near the top of the Chagrin formation on Chippewa Creek.
5. Ventral valve.
6. "Squeeze" of an external impression of a dorsal valve with mucronate extension of hinge line. Only one point is preserved on the specimen. Both specimens from near the top of the Chagrin formation on Brandywine Creek below the falls.

Figs. 7, 8.	*Reticularia præmatura* (Hall) Schuchert. --------------------	535

7. Ventral valve showing concentric ridges and furrows and interrupted radiating lines.
8. Exfoliated dorsal valve showing same surface markings and somewhat indistinctly marked fold. Both specimens from roadside, 2 miles east of Trumbull Center.

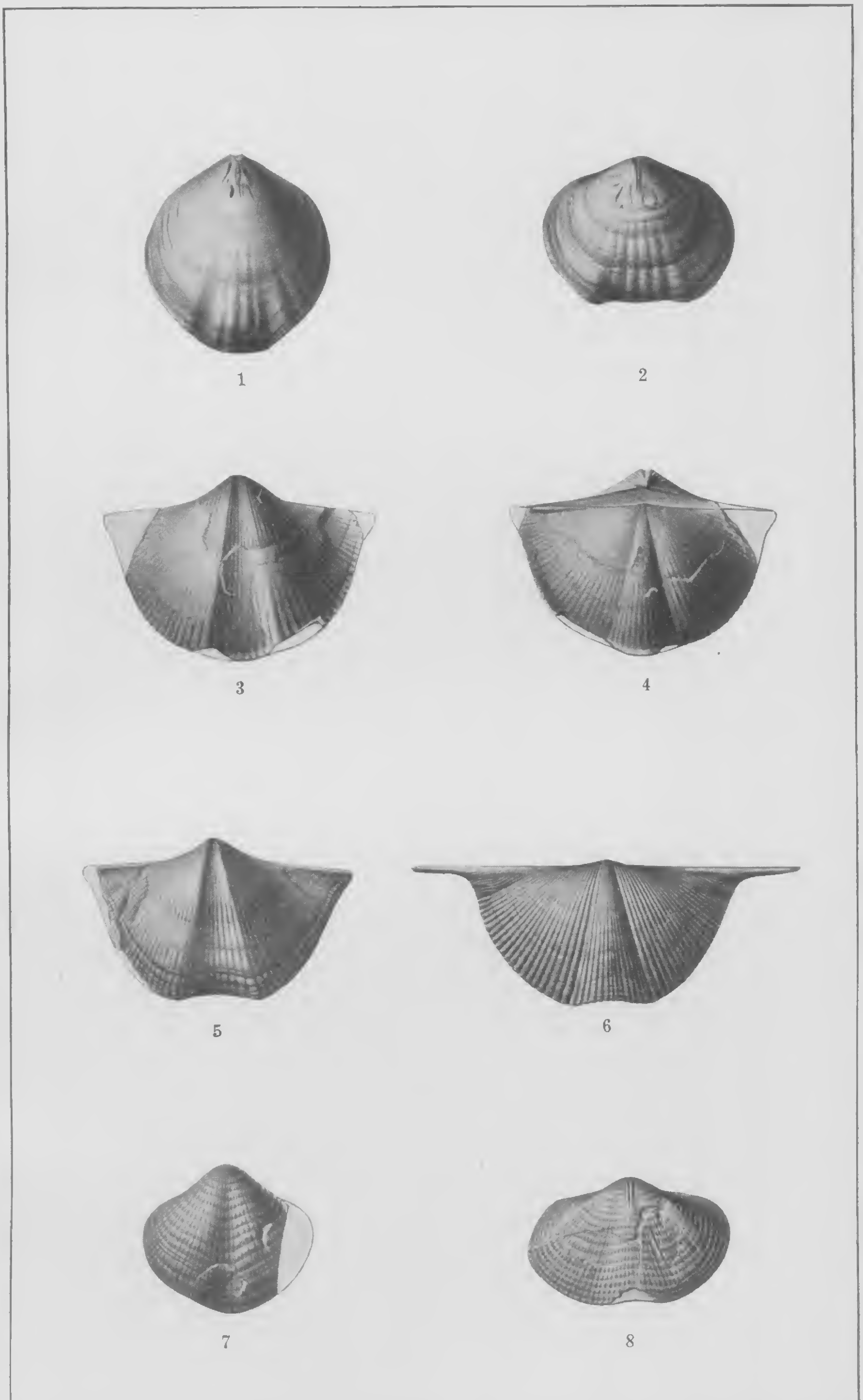

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PLATE LXIX

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Figs. 1–4.	*Cyrtia alta* Hall.	536

1. Internal impression of ventral valve showing sinus with muscular impressions, faint plications toward its front and on the sides, and sinuate outline of front of valve.
2. Cardinal area of same specimen showing delthyrium, transverse delthyrial plate and forward inclination of beak.
3. Partly exfoliated cardinal area of ventral valve of smaller specimen showing delthyrium and transverse delthyrial plate. Both specimens from near top of Chagrin formation on Chippewa Creek and loaned by Professor Cushing from the Adelbert College collection.
4. Cardinal area of ventral valve showing delthyrium and transverse delthyrial plate with concentric lines. Hinge area both vertically and transversely lined. Madison-Thompson road, 3 miles south of Madison.

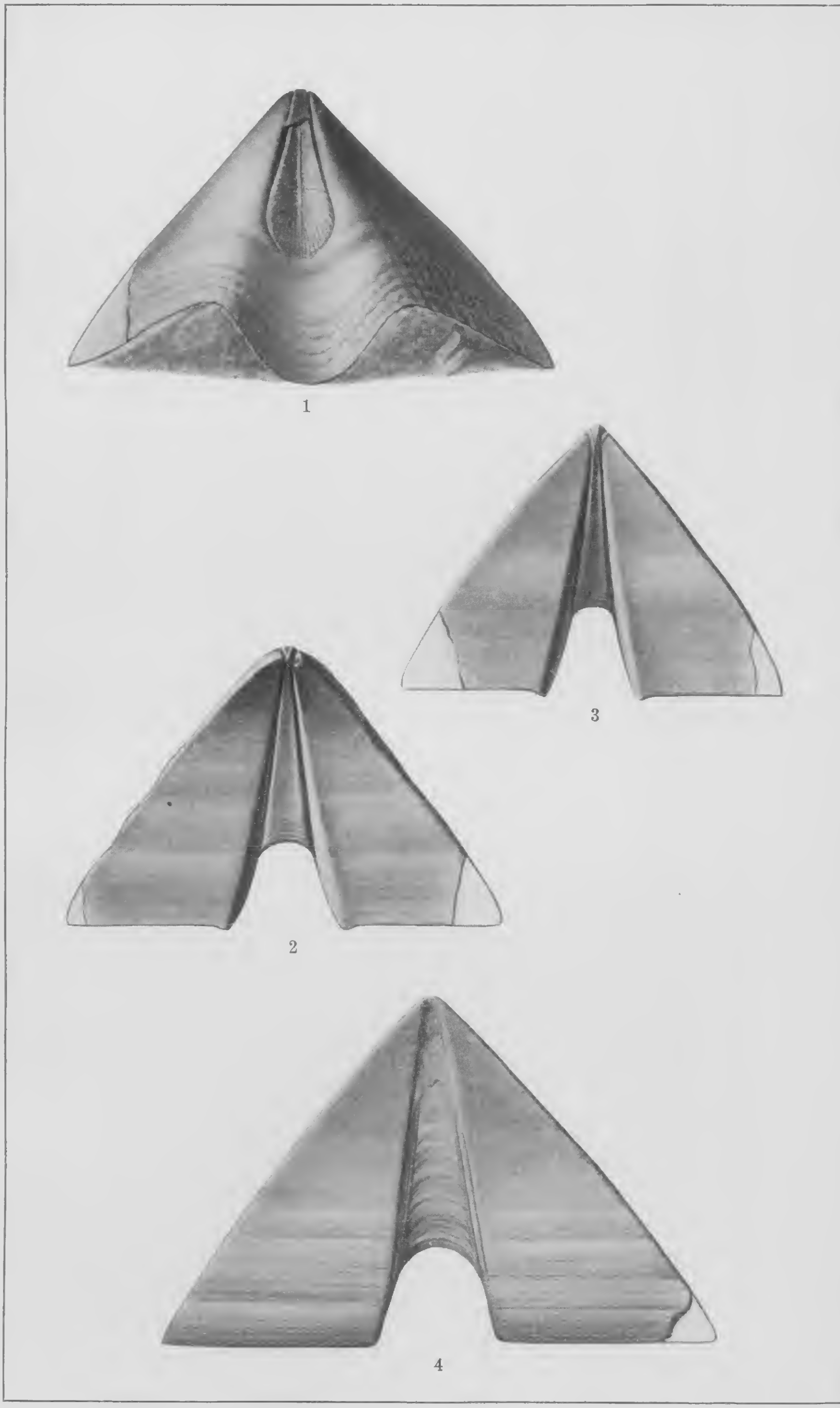

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PLATE LXX

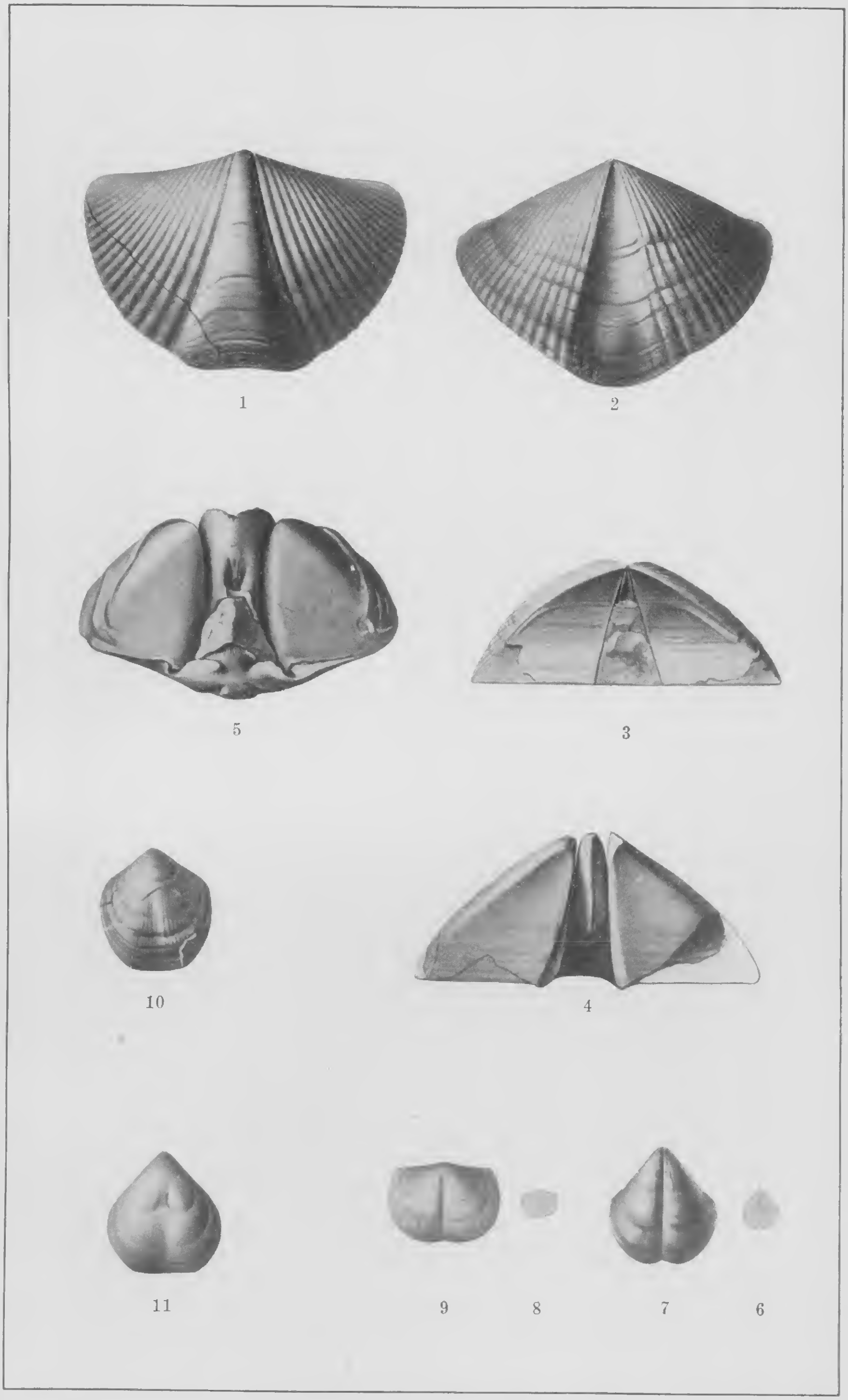

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PLATE LXXI

PLATE LXXI.

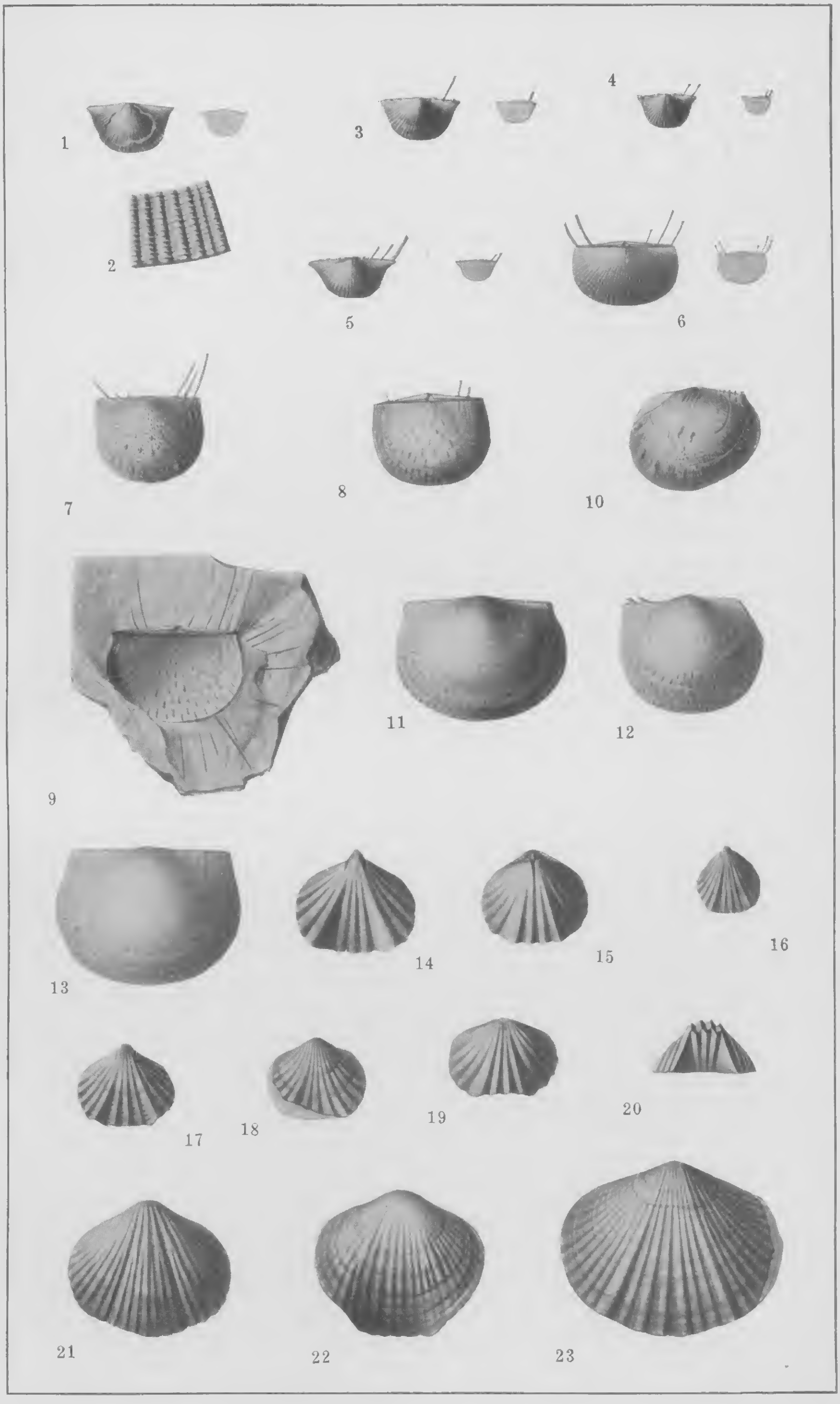

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PLATE LXXII

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Figs. 1–4.	*Liorhynchus clarkei* n. sp.	545
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	2. Partly exfoliated dorsal valve.	
	3. Internal impression of dorsal valve.	
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	12. Partly exfoliated interior of dorsal valve.	
	13. Partly exfoliated ventral valve.	
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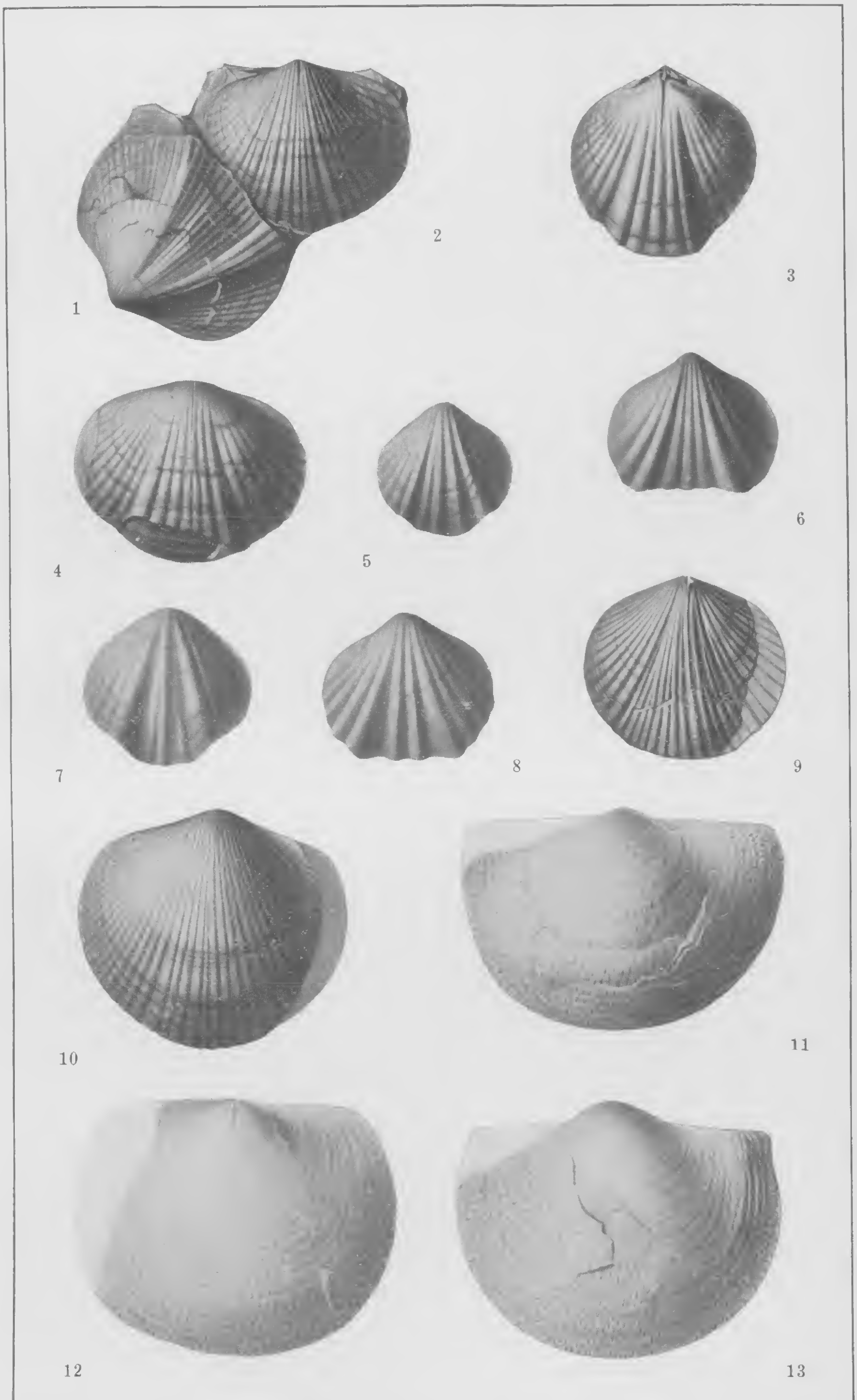
PLATE LXXII.



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AREAL GEOLOGY

SURFICIAL GEOLOGY

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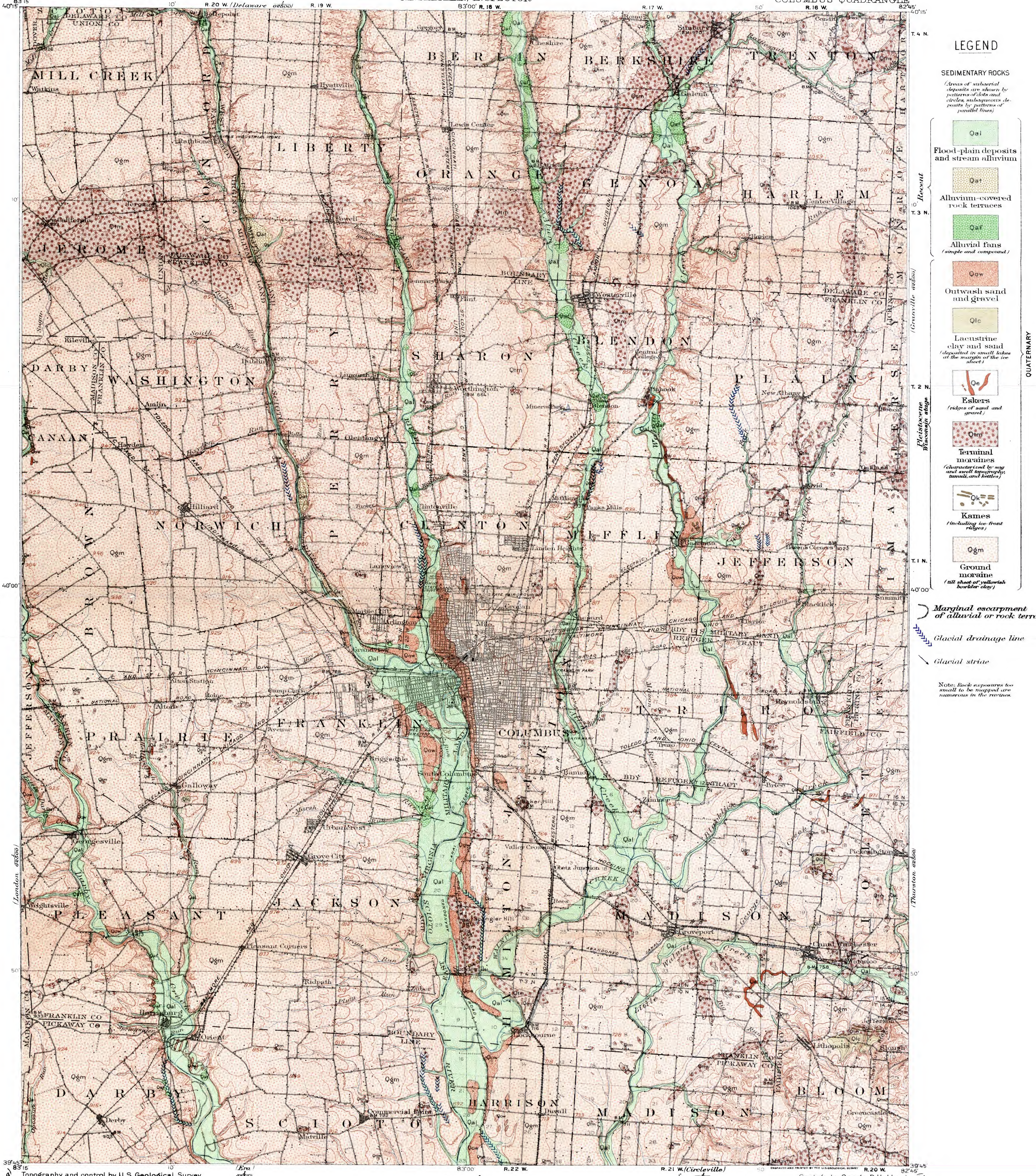
OHIO
COLUMBUS QUADRANGLE



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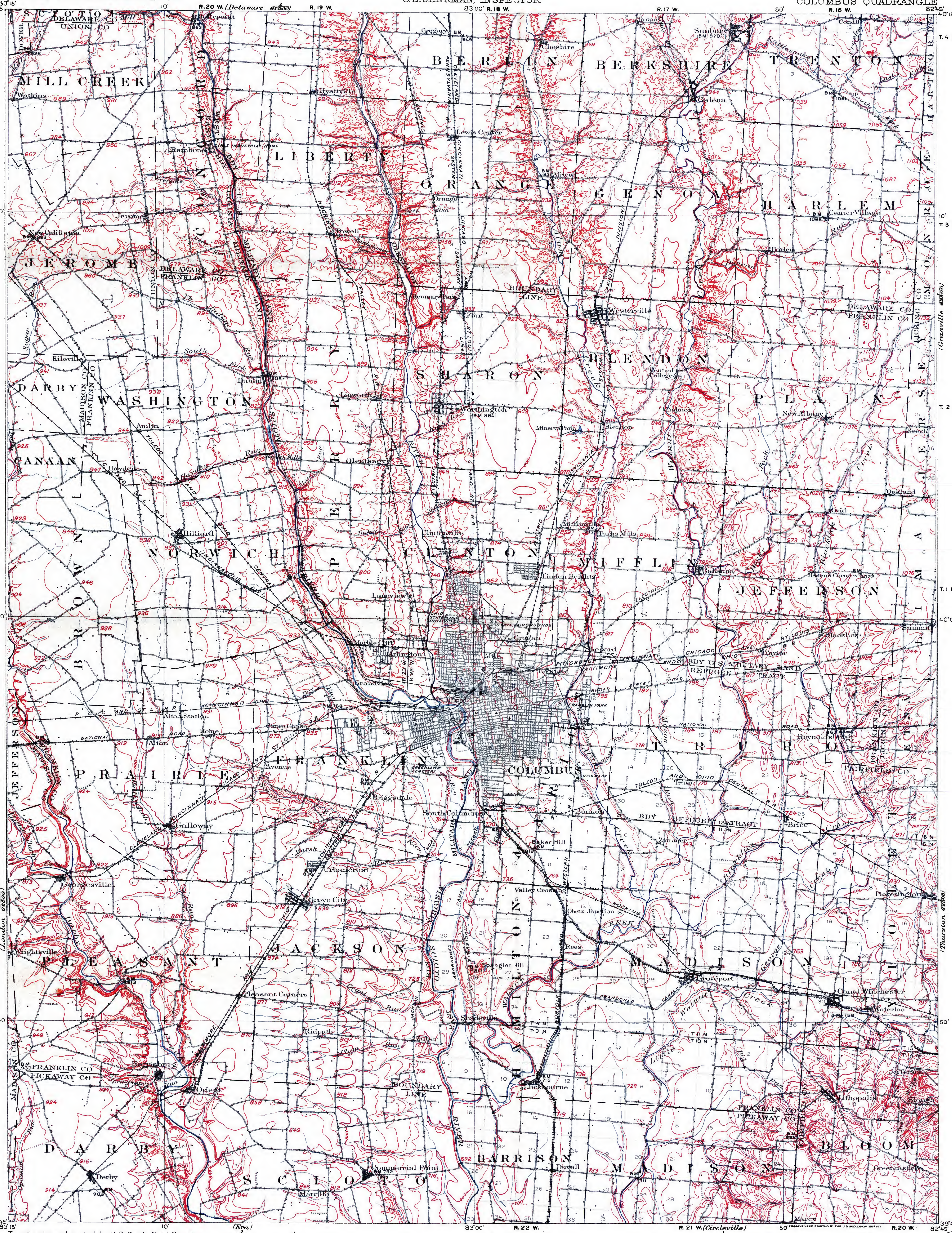

LEGEND

RELIEF
printed in brown

Altitude
above mean sea level instrumentally determined

Contours
showing height above sea, horizontal form, and steepness of slope of the surface

Depression contours

DRAINAGE
printed in blue

Streams

Intermittent streams

Abandoned canal

Lake or pond

CULTURE
printed in black

Roads and buildings

Cemetery

Private or secondary roads

Railroads

Electric railroad

Bridge

U.S. township and section lines

County line

Township line

City, village, or borough line

Triangulation station

Bench mark
showing precise altitude

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1 ½ 0 1 2 3 4 5 Miles

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